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# EDUCATOR'S GUIDE FOR MISSION TO EARTH: LANDSAT VIEWS THE WORLD

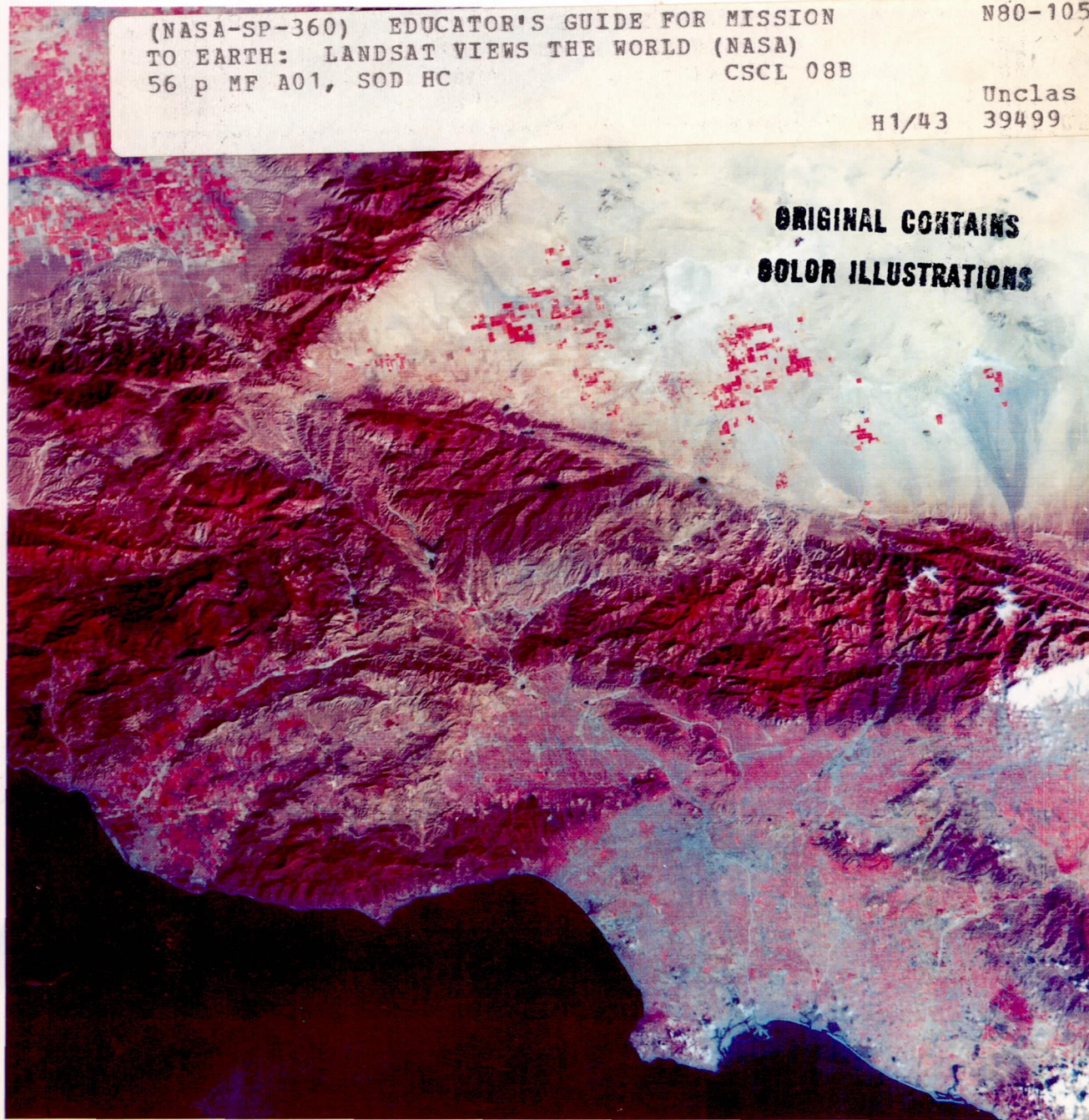
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This educator's guide is designed to accompany NASA SP—360, *Mission to Earth: Landsat Views the World*, which is for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. The activities suggested in this guide are dependent upon the color lithographs reproduced in *Mission to Earth* . . .



**EDUCATOR'S GUIDE for**  
**MISSION TO EARTH:**  
**LANDSAT VIEWS THE WORLD**

NASA SP 360



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1978

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## PREFACE

Since the launching of the first Landsat in the summer of 1972, scientists have become increasingly more aware of the satellite and its imagery of the earth.

During the past several years, the unabashed enthusiasm of Goddard scientists and engineers, the experimentation with ways of using Landsat imagery with teachers in numerous workshops sponsored by Goddard's Educational Programs Office, and the conception of *Mission to Earth* . . . as a compendium of the best of Landsat, all served as incentives to the development of this guide.

The Educator's Guide is an effort to offer teachers some suggestions for using Landsat imagery in their classrooms. Moreover, it is an attempt to excite teachers in various disciplines and at various levels about the uses and great potential of Landsat as an educational tool.

The author is indebted to many people at Goddard Space Flight Center who assisted in the preparation of this guide. Persons from a

variety of disciplines who were particularly helpful include the authors of *Mission to Earth*, Nicholas M. Short, Paul D. Lowman, Jr., Stanley C. Freden, and William A. Finch, Jr. In addition the author wishes to thank Herbert Tiedemann, Jeffrey Kowal, Charles Boyle, and Ira Kolmaister for their assistance.

Special thanks is given to Elva Bailey, Educational Programs Officer for providing an environment which encouraged the development of this guide.

The author is deeply indebted to Richard Crone and Lurie Shima of Goddard's Educational Programs Office for their tireless efforts as consulting editors.

Finally, the author would like to thank all those teachers who used many of these materials in workshops and who offered constructive criticisms and suggestions for classroom uses of Landsat imagery.

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## INTRODUCTION

This guide has been prepared for use with NASA SP 360, *Mission to Earth: Landsat Views the World* by Nicholas M. Short, Paul D. Lowman, Jr., Stanley C. Freden, and William A. Finch, Jr. (available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.) It is specifically designed to provide teachers with information and suggestions for using Landsat imagery to teach basic concepts in several content areas.

The guide must be used in conjunction with *Mission to Earth* . . . to be of any value to the teacher. All background information relative to the history and technology of Landsat, the concept of remote sensing, how images are obtained and interpreted, and detailed information about each scene in the book is not included in this guide, but can be found in *Mission to Earth*. . . . Within this guide reference is also made to specific information, diagrams, and illustrations which are also found in *Mission to Earth*. . . .

It is generally recognized that the Landsat program represents a major breakthrough in our ability to learn and know more about our global environment. The information transmitted to earth from Landsat is making it possible for us to uncover hitherto unknown facts about our planet and its condition, and by virtue of a better perspective, to see in a new way what we were already aware actually existed.

One aspect of the Landsat program which

has direct implications for educators is that the images returned by the spacecraft can be utilized to supplement and complement classroom instruction in various disciplines.

Landsat imagery holds promise of being important in helping students become more aware of the world in which they live. If this can be considered a basic objective of education at all levels, it is necessary that educators find realistic and efficient approaches to meet this objective.

It is difficult, at best, to adequately equip young people for the future by using only those tools and techniques which are most comfortable and secure, or by transmitting only the information which is familiar. Generally, there exists a need to devise new strategies and creative approaches to learning, and to stress the unknown and unfamiliar. Landsat imagery offers one such alternative tool for use in instructing students about the earth. It is hoped that this guide will make it possible for the teacher to understand and use Landsat imagery as an effective instructional tool. Each image contains so much information that teachers and students in many discipline areas will find much of interest and value.

It is hoped, moreover, that the information given in this guide will serve as a beginning—a challenge—extended to each teacher to use this guide, not as a text, but as a springboard from which to devise new strategies for studying, interpreting, and using Landsat imagery in the classroom.



CHAPTER

1

# A RESOURCE FOR TEACHERS



# A RESOURCE FOR TEACHERS

This chapter is specifically designed to provide the upper elementary and junior high school teacher with ideas and suggestions for effective classroom instruction using Landsat images.

Included within this resource section are a variety of ideas which can be used by the teacher to help students understand basic concepts and principles in several content areas.

The materials included here are organized around four broad content themes, namely; (1) EARTH SCIENCE—GEOLOGY; (2) ENVIRONMENTAL STUDIES; (3) GEOGRAPHY; and (4) SOCIAL AND URBAN STUDIES.

The organization of this chapter around specific Content Themes in no way precludes the use of ideas and activities other than those mentioned. It is hoped that the teacher's imagination will be stimulated and that this guide will generate other ideas and techniques for using Landsat imagery in classroom instruction.

Finally, it is hoped that this chapter will provide the teacher with some assistance in making it possible for students to "see the earth for the first time," and realize the potential of satellite imagery as a means of learning about our earth, its resources and conditions.

## TECHNIQUES OF LANDSAT IMAGE INTERPRETATION

It has been found that trained observers have the ability to distinguish between various land classes such as undeveloped land, urban and agricultural areas on Landsat images, and to further break down these classes into meaningful subclasses. In agricultural areas, the subclasses can be delineated on the basis of

general tone and texture differences of colors that relate to crop type, vigor, maturity, and field size.

The synoptic view afforded by a single frame of Landsat imagery is shown in *Mission to Earth . . .*, Plate 126, Bay Area, California.

This introductory exercise is designed to acquaint the teacher with simple techniques which can be used in interpreting Landsat images.

To aid you in appreciating and interpreting Landsat imagery, the following color definitions are provided:

- 1) *Red-magenta*—denotes vigorous vegetation, i.e., forests, farmlands (agriculture) near peak growth. Detailed study of different shades of red aid in classification of different types of vegetation as well as the determination of their growth cycle and general health.
- 2) *Pink*—depicts less densely vegetated areas and/or vegetation in an early state of growth. Suburban areas around major cities with their green lawns and scattered trees normally show up pink.
- 3) *White*—areas of little or no vegetation but of maximum reflectance. White areas include: snow, clouds, deserts, salt flats, ground scarring, fallow fields, and sandy beaches.
- 4) *Dark Blue to Black*—normally identifies water, i.e., rivers, streams, lakes, reservoirs. In the western U.S. particularly Idaho and New Mexico, the very dense black features are ancient lava flows rather than water bodies.
- 5) *Gray to Steel Blue-Gray*—indicates towns, cities, urban, populated areas. The colors are produced by the returns from asphalt, concrete and other man-made features.
- 6) *Light Blue in water areas*—denotes either very shallow water or heavily sedimented water.
- 7) *Light Blue in western areas*—identifies desert shrubland capable of supporting limited grazing activities.



- 8) *Brown, Tan, and Gold*—locates areas comprised primarily of open woodlands (pinon, juniper, aspen, chaparral) and rangeland suitable for grazing.

To complete this activity you will need in addition to Plate 126, a map of the Bay Area, California and the descriptive caption for Plate 126. The caption is reproduced below.

Using these data, do the following:

1. Familiarize yourself with the San Francisco Bay area by reading the caption, checking conventional maps or atlases, and using other sources.
2. Make four overlays using sheets of clear acetate or plastic. Locate each feature listed in step 3 and label them on the appropriate overlay using a marking pen. (Note: Any feature referred to in the image caption can be located within one grid cell using the letter-number grid system found along the margins of each image. An explanation of this system is found in *Mission to Earth* . . . , pp. vi-vii.)

3. To assist you in locating features on the image, the diagrams on pages 5, 6, and 7 may be reproduced as overlays and used with Plate 126.

Overlay 1

- a. Cities
- b. Faults
- c. Mountain ranges

Overlay 2

- a. Major vegetated areas (remember! red coloration)
- b. Vegetation types shown, i.e., forest, grassland, cropland

Overlay 3

- a. Residential communities
- b. Major roads and highways
- c. Waterways
- d. Reservoirs
- e. Salt pans

Now that you have tried some of the techniques of image interpretation, the next step is to look at image analysis in greater detail.

---

(The following is a corrected caption for Plate 126, in *Mission to Earth* . . . )

**THE BAY AREA, CALIFORNIA:** This spectacular view of northern California shows many well-known cities: San Francisco (C-8), Oakland (E-7), San Jose (J-12) and others clustered around San Francisco Bay (E-9) and San Pablo Bay (C-4), Santa Cruz (J-17), Salinas (O-20) and Monterey (M-22) to the south, and Stockton (O-3) and Modesto (R-7) in the Great (Sacramento) Valley (Q-5) of central California. Recent landfill (F-10) and salt evaporation basins (I-1) are evident in the south part of the Bay.

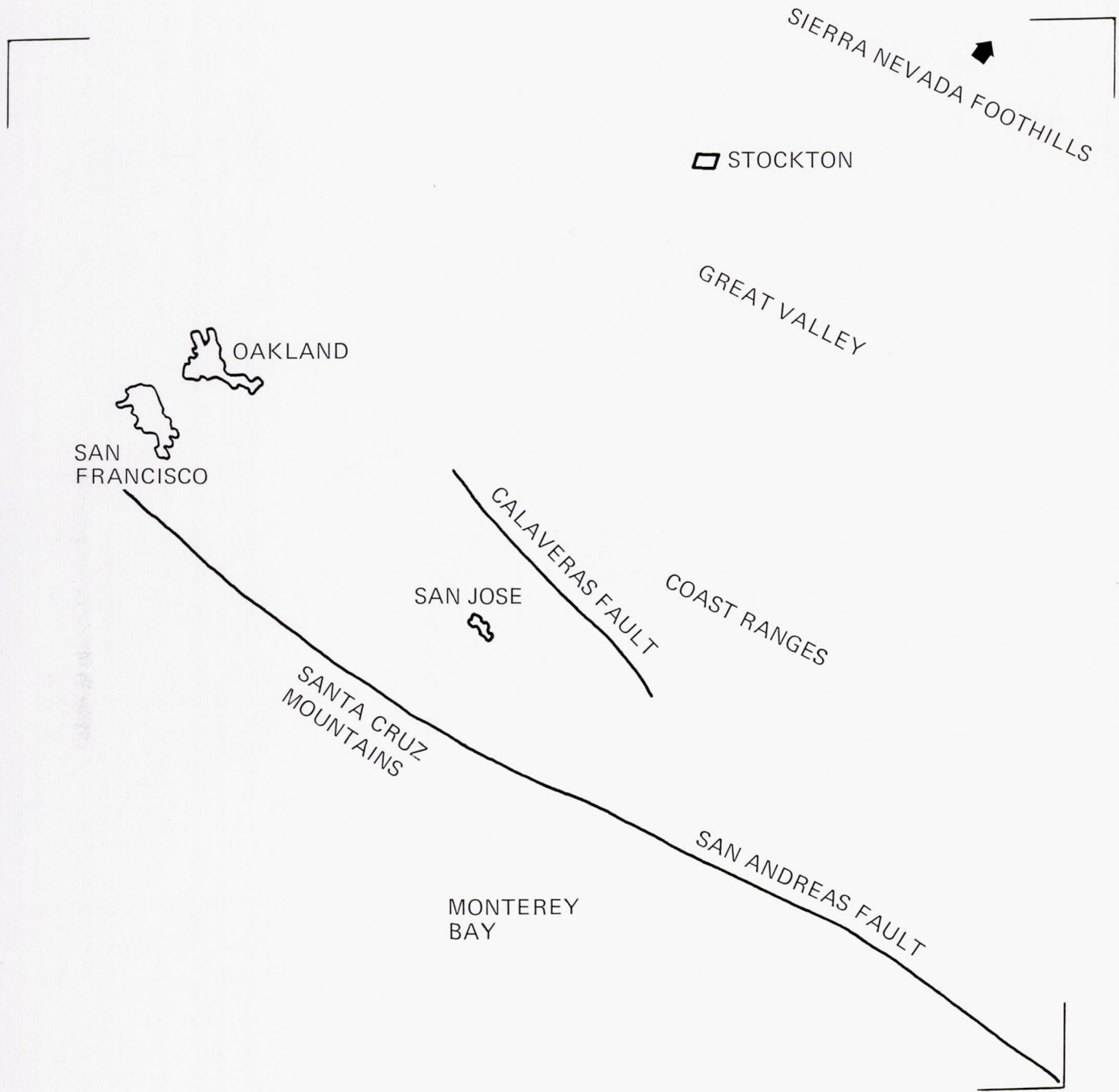
Geologically, the area west of the Sacramento Valley includes the intricately folded Coast Ranges (O-12) composed of Mesozoic metamorphic rocks and Cretaceous and Tertiary marine sediments. Several active faults include the famed San Andreas (whose trace is emphasized by the Crystal Springs Lake (E-11), which occupies the fault valley west of San Mateo) and the Hayward (H-9) and Calaveras (J-10) faults in the East Bay region, Mount Diablo (H-6), the highest (1173 meters [3849 feet] ) peak in the Bay area, is a fault-bounded piercement structure made up of greenstone and serpentine. The edge of the Sierra Nevada foothills (U-1) appears to the east of the Quaternary sediment-filled Great

Valley.

The Santa Cruz Mountains (H-15) contain the southernmost Redwood forest—indicated by the deep reds—along the California coast. The hills to the north and east of the Bay area and southward support California Oaks and evergreens (such as the imported Eucalyptus trees) mixed with chaparral in places. The eastern slopes (R-13) of the Coast Ranges are covered with grasses that turn a distinctive golden brown in summer. (Please note that the caption for plate 126 in *Mission to Earth* . . . contains a typographical error. R-3 should read R-13.) Tule marshes dominate the delta country (H-3) near the mouth of the Sacramento River.

The region includes a diversity of farm products, including truck crops in the Salinas Valley (P-21) and grapes in the Santa Clara (O-16) and Great Valleys. The Sacramento Valley is used almost entirely to farm such cash crops as rice, cotton, barley, sunflower, sugar beets, beans and tomatoes. Some fields have been burned after harvest (I-2). Peach trees are also common in the Valley and walnut groves abound in the warm climates of the valleys east of the ranges near the fog zone of the coast. 1075-18173; October 6, 1972.



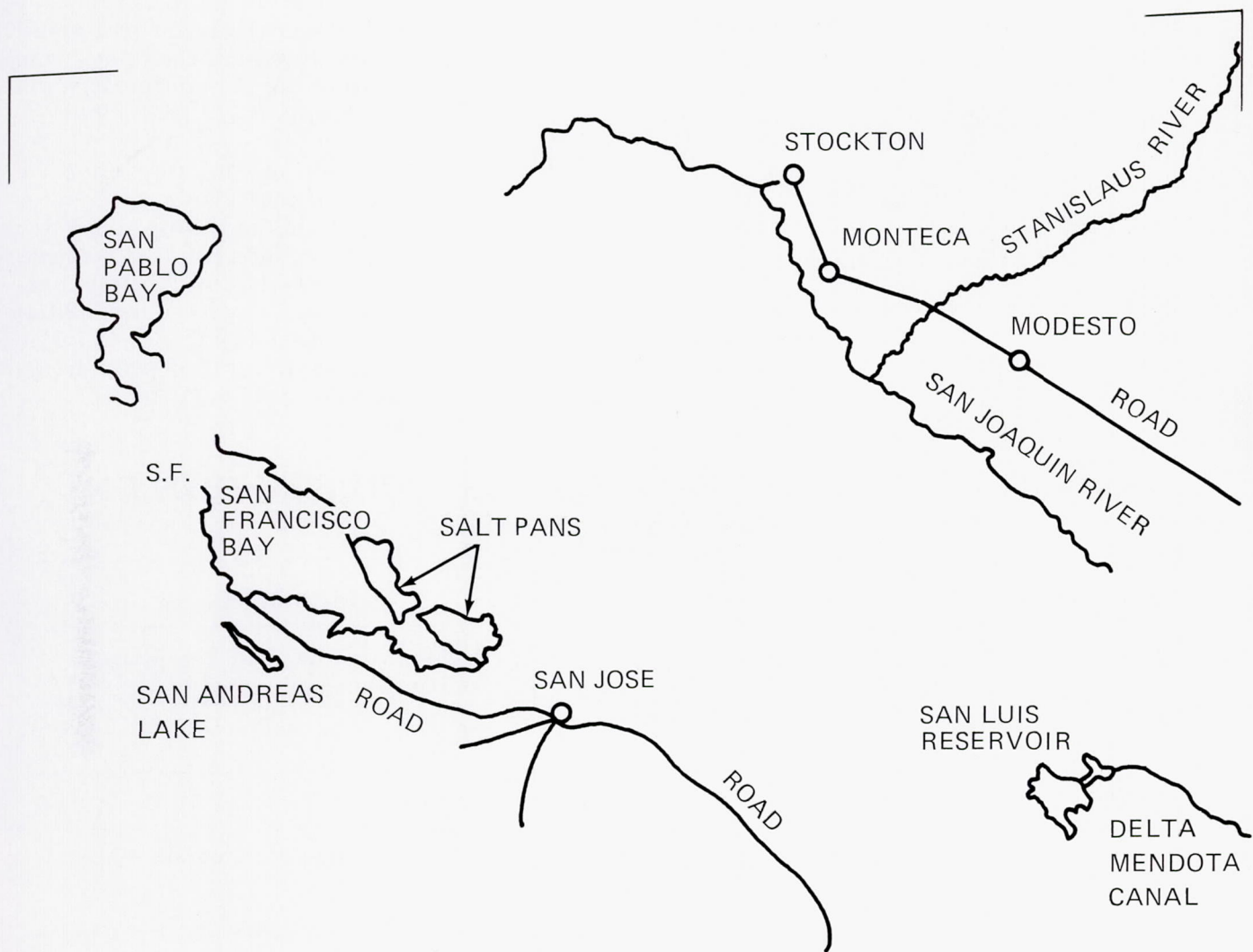


OVERLAY 1



OVERLAY 2





OVERLAY 3

## INTRODUCTORY STUDENT ACTIVITY

### ACTIVITY 1: OBSERVING AND IDENTIFYING SEASONAL VARIATIONS ON LANDSAT IMAGES

1. Select images from *Mission to Earth*. . . Some images which are well suited for this activity are:

Plate 3—Seasonal effects around Washington, D.C.

Plate 4—Delmarva Peninsula

Plate 42—Mississippi River Flood Sequence

Plate 86—Six Views of Canyon Lands

2. Discuss with the students the background information on page 9, and the Guide for Studying Seasonal Variations on Landsat Images, found below.

3. Show the students the images (make sure the image location is concealed.)
4. Have students "guesstimate" the season of the year when each image was taken. Have students justify their "guesstimates".
5. In cases where estimates are incorrect, tell students the date on which the image was made. This information is found in *Mission to Earth*. . . , Appendix C "Index of Plates," pp. 453-459.
6. Identify the location of each image for the students or give the students the center coordinates (latitude and longitude) for each scene and have them find the location on a world map or in an atlas. (Center coordinates for each image may be found in *Mission to Earth*. . . , Appendix C, pp. 453-459. Please note that as a result of processing, center coordinates may vary by plus or minus 10 km).

### GUIDE FOR STUDYING SEASONAL VARIATIONS SHOWN ON LANDSAT IMAGES

Season	Color Code	Additional Clues
Fall	<p><i>Forest Region</i>—Red for all trees</p> <p><i>Crop Areas</i>—Varies from light pink to light brown or gray</p>	Land plots of harvested crops are mostly white and gray
Winter	<p><i>Forest Region</i>—Red for evergreens, deep brown or gray for annual shedding trees</p> <p><i>Crop Areas</i>—Basically light brown to gray</p>	<p>Snow cover</p> <p>Snow caps</p> <p>Longer shadows of mountain ranges</p>
Spring	<p><i>Forest Region</i>—Red to light red for evergreens, pale pink or light gray for annual shedding trees and herbaceous vegetation</p> <p><i>Crop Areas</i>—Basically light pink to light brown</p>	River and stream boundaries have more detail and can be traced further inland
Summer	<p><i>Forest Region</i>—Purplish red for all trees</p> <p><i>Crop Areas</i>—Basically pink in color with some red and gray plots</p>	Very few shadows showing the outline of mountain ranges geometric pattern of fields



## BACKGROUND INFORMATION FOR OBSERVING AND IDENTIFYING SEASONAL VARIATIONS ON LANDSAT IMAGES

Explain to the students that *red* and *tints of red* represent vegetation. The kinds of vegetation appearing red could be trees, shrubs, crops and various annual grasses or anything green growing on the earth. Arid regions, which lack vegetation, appear light brown or white. Urban areas, such as cities and towns, appear blue gray. (Note: relatively moist plowed fields also appear blue-gray.)

Water appears dark blue or black. Rivers and bodies of water transporting relatively large quantities of mud and silt appear light blue. Mountainous terrains are easily identified by a dendritic (branching like a tree) drainage pattern or other similar patterns caused by the many rivers and streams. They can also be identified by snow-capped peaks. (Note: Don't confuse snow with clouds. Clouds are located above the earth's surface and will cast a shadow on the earth's surface adjacent to the cloud. The shadow conforms to the shape of the cloud. The amount of shadow seen is determined by the sun angle.)

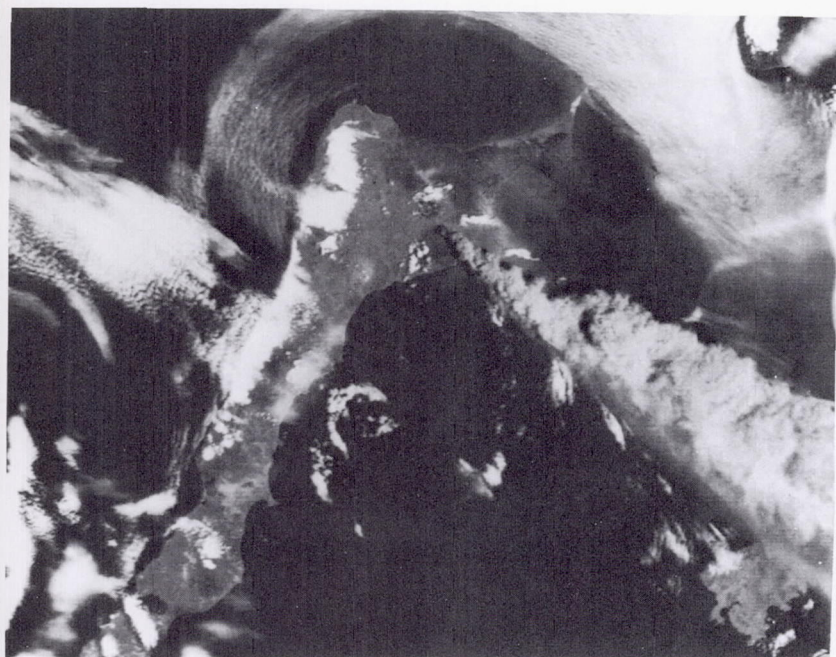
## CLASSIFICATION OF LANDSAT IMAGERY BY CONTENT THEME

Selected Landsat images which can be used advantageously in teaching various concepts in the four selected Content Themes presented in this Guide are listed with the activities for each Content Theme. All of these images can be found in *Mission to Earth*. . . . Each image in *Mission to Earth* . . . is given a plate number, for example, Plate 126 Bay Area, California. The plate number can be used to locate each Landsat scene and to reference additional information about each scene from Appendix C, "Index of Plates," in *Mission to Earth* . . . pp. 453-459. Each image suggested in this Guide will be listed by scene title and plate numbers will be given in parentheses, for example, Los Angeles, CA (129).

The plates suggested for each Content Theme represent a small portion of the total number of images found in *Mission to Earth*. . . . All of the images found in *Mission to Earth*. . . can be used in teaching a variety of concepts from many disciplines.

It is hoped that the users of this Guide will be able to select from *Mission to Earth* . . . images other than those suggested for each content theme and use them in teaching the concepts presented within this Guide. Moreover, the user is also encouraged to identify other Content Themes or disciplines not mentioned in the Guide and to select from *Mission to Earth* . . . appropriate images illustrative of each.





CHAPTER

2

CONTENT THEME:

# EARTH SCIENCE— GEOLOGY

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# EARTH SCIENCE— GEOLOGY

Earth Science is a broad area of interdisciplinary study of the physical earth. Technically, however, there is no distinct discipline known as earth science; rather there are several fields of science which focus on the particular aspects of the physical earth. Primarily it is the intent of the Earth Sciences to attempt to relate the earth to the larger universe. Broadly speaking, the Earth Sciences include meteorology, oceanography, geology.

One of the oldest Earth Sciences is geology, which is the study of the Earth, its structure, composition, and history. Geology includes physical geology, historical geology, mineralogy, petrology, paleontology, geomorphology, and other specialties.

Included within the scope of the Earth Sciences is the study of the physiography of remote areas; studies of seismic and other tectonic activity; mapping gross geologic structures, such as rock fractures, fold patterns, and other changes in the earth's landforms.

## SUGGESTED IMAGES FOR STUDYING EARTH SCIENCE—GEOLOGY

Finger Lakes, New York	(8)*
Harrisburg, Pennsylvania	(14)*
Atlanta, Georgia	(18)*
Nashville Dome and Basin	(29)
Colorado Rocky Mts.	(76)*

\*Referred to in activities in this chapter.

Uranium Country, Utah-Colorado	(77)*
North-Central Arizona	(83)*
Northwest New Mexico	(84)*
Canyon Lands, Southeast Utah	(85)*
Grand Canyon, Arizona	(87)
San Rafael Swell, Utah	(91)
Yellowstone National Park	(98)*
Bighorn Mts., Wyoming	(99)*
Southern Idaho	(101)*
Portland, Oregon	(110)*
Cascade Range, Oregon	(111)*
Basin and Range Country, Oregon and Nevada	(112)
Monterey Bay	(125)*
Bay Area, California	(126)
Imperial Valley, California	(133)*
Island of Hawaii	(135)*
"Finger Lakes" of Alaska	(143)
Sierra Madre Orientale, Mexico	(184)
Managua, Nicaragua	(193)*
Amazon River	(205)*
Norway	(222)
Scotland	(225)
Pyrenees	(230)
Rhine and Ruhr Valleys	(237)
Italy	(241)*
Dalmation Coast of Yugoslavia	(246)*
Tigris and Euphrates Rivers	(276)*
Tibetan Plateau	(299)
Brahmaputra River	(301)*
Yellow River	(315)*
Dormant Volcano Awakens	(322)*
Southern Morocco	(323)
Atlas Mountains	(324)
Zaire (Congo) River	(339)*
Afar Depression	(366)
Pilbara District, Australia	(379)



## ACTIVITY 2: IDENTIFICATION AND STUDY OF DRAINAGE PATTERNS

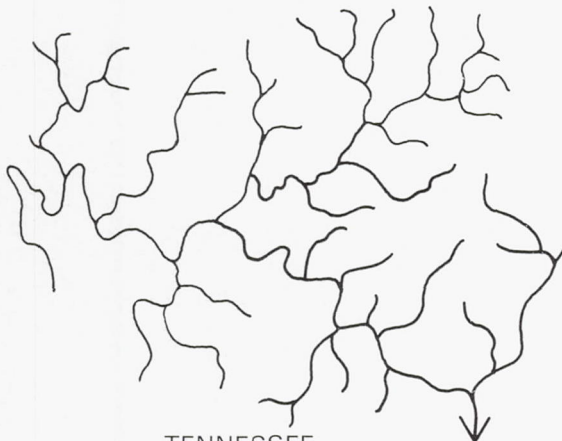
Different types of underlying geologic structure result in various types of drainage patterns on the earth's surface. The four major drainage patterns are illustrated below:

The most common drainage pattern is the *dendritic*. This tree-like pattern usually forms on flat or nearly flat-lying material which is relatively uniform in its ability to resist erosion. *Radial* drainage occurs around a central dome or mountain which has streams flowing outwardly in all directions. *Trellis* drainage consists of a rectangular or trellis-like pattern of relatively straight streams which meet each other at right angles. This usually occurs

where there are alternating linear ridges and valleys formed by faulting or folding. *Annular* drainage, like the trellis, is structurally controlled, but develops over well-defined domes or basins, forming curved rather than rectilinear patterns.

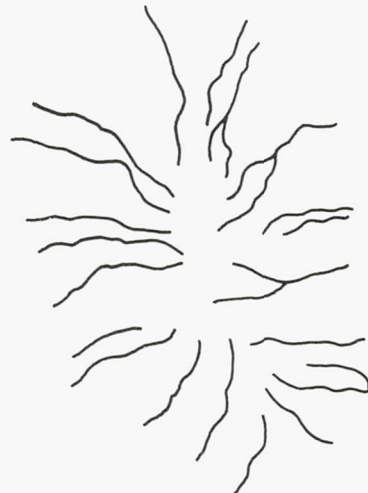
1. Using the above information and diagrams, have students identify as many different drainage patterns as possible on Landsat images. Students should be encouraged to associate each type of drainage pattern with the geologic structure of the area shown on the image. Suggested plates for this activity are:
  - a. Plate 205—Amazon River
  - b. Plate 276—Tigris and Euphrates River
  - c. Plate 301—Brahmaputra River
  - d. Plate 315—Yellow River
  - e. Plate 339—Zaire (Congo) River

### DENDRITIC DRAINAGE



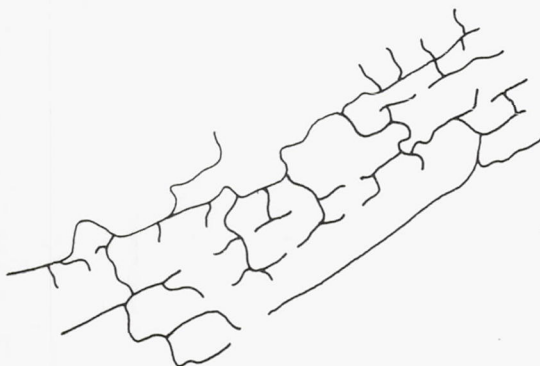
TENNESSEE  
APPALACHIAN PLATEAU

### RADIAL DRAINAGE



HAWAII-MAUI  
CRATER

### TRELLIS DRAINAGE



TENNESSEE  
VALLEY & RIDGE

### ANNULAR DRAINAGE



OUACHITA MTS  
(MODIFIED)



### ACTIVITY 3: LOCATING AND IDENTIFYING GROSS GEOLOGICAL FEATURES

Have students locate in *Mission to Earth*. . . examples of the geological features listed below:

Feature	Suggested Plates in <i>Mission to Earth</i> . . .
a. Fault	125 - Monterey Bay
b. Volcano	135 - Island of Hawaii
c. Lineament	18 - Atlanta, GA
d. Finger lakes	8 - Finger Lakes, NY
e. Canyon	76 - Colorado Rocky Mts.
f. Plateau	77 - Uranium Country, Utah— Colorado
g. Mesa	84 - Northwest New Mexico
h. Karst topography	246 - Dalmatian Coast of Yugoslavia
i. Lava flow	101 - Southern Idaho
j. Alluvial fan	133 - Imperial Valley, CA
k. Graben	83 - North-Central Arizona
l. Cuesta	84 - Northwest New Mexico
m. Anticline	99 - Bighorn Mts., Wyoming
n. Syncline	14 - Harrisburg, PA
o. Geyser field	98 - Yellowstone National Park

Note: Students may need to refer to the caption accompanying each image for additional clues to help them identify these features. Atlases and other maps will also be very useful in completing this activity.

### ACTIVITY 4: IDENTIFYING AND STUDYING GLACIAL FEATURES FROM LANDSAT IMAGERY

1. Have the students consult a physical geography or earth science textbook to identify areas of the world most recently (geologically speaking) affected by glaciation. (See Bibliography, page 51).
2. Students should list glacial features and their characteristics.
3. Using the lists which they have compiled and the captions accompanying each Landsat image, have students pick out as many glacial features as possible on Landsat images, and describe/discuss the characteristics of each.

### ACTIVITY 5: STUDYING VOLCANISM AND ITS IMPACT UPON THE ENVIRONMENT

1. Define the following types of features which result from or are associated with volcanism, and show the students examples of each in *Mission to Earth*. . . (Note that definitions may be found in *Mission to Earth*. . . Appendix B, "Glossary of Technical Terms," pp. 443-451 and in this Guide, in the Glossary of Terms, pp. 55.)

Feature	Suggested Plates
a. Crater Lake	193 Managua, Nicaragua
b. Caldera	111 Cascade Range, Oregon
c. Active volcano	241 Italy
d. Dormant volcano	322 Dormant volcano awakens
e. Lava flow	101 Southern Idaho
f. Strato-volcano	110 Portland, Oregon
g. Igneous intrusion	85 Canyon Lands, Southeast Utah

2. Have the students find examples of these features from *Mission to Earth*. . .
3. Have students select one image from among those showing volcanic features and do the following:
  - a. Observe the land use and other geologic and/or geographic conditions of the area shown on the image. (Note that these areas tend to be heavily vegetated).
  - b. Prepare a brief discussion on the impact of volcanic activity in the area. Include in your discussion any indication of how man is using the area and why it is being used.

### ACTIVITY 6: LOCATING SURFACE FEATURES ON LANDSAT IMAGES

1. Assign each student an image from among those suggested for the Earth Science—Geology Content Theme, page 13.
2. Have students overlay a piece of clear plastic or acetate over the image and trace or

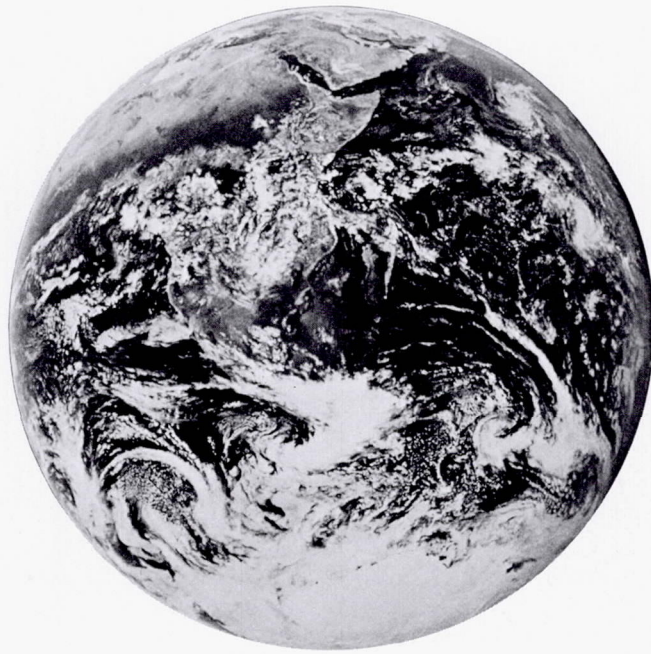
label as many faults, lineaments, and other geologic surface features as possible.

3. Students should check their overlays for accuracy with a topographic or other geologic map of the study area. The descriptive caption which accompanies each image in *Mission to Earth*. . . should also be consulted for purposes of information and comparison.

## **ACTIVITY 7: MAPPING TECTONIC FEATURES AND ROCK TYPES**

1. Select several images from among those listed for the Earth Science—Geology Content Theme on page 13.
2. Prepare two overlays for each image selected:
  - a. Overlay 1 — Identify tectonic features (faults, joints, pipes, and others.)
  - b. Overlay 2 — Identify major rock types (igneous, sedimentary, metamorphic) shown on the image.
3. Place *both* overlays on the image and do the following:
  - a. Observe and briefly describe the relationship between the linear features and the rock types in the area studied.
  - b. Using the caption accompanying each image and corresponding geologic maps, indicate whether the predominant rock types are igneous, sedimentary, or metamorphic.
4. Carry out further research and discuss the major geologic forces which were or are operating in the area studied, and which have affected the rock structure of the area.





**CHAPTER**

**3**

**CONTENT THEME:  
ENVIRONMENTAL  
STUDIES**



# ENVIRONMENTAL STUDIES

Environmental studies encompass a broad spectrum of topics which are considered vital to man's survival. There is great emphasis upon such environmental issues as air, water, and noise pollution; water quality; solid waste disposal; desecration of the landscape; resource management and conservation; protection of wilderness areas and endangered species; development of coastal wetlands; and land management policies and practices.

Environmental studies include a study of man's relationship to his environment and its natural resources. It also includes the study of the interrelationship between the biological, physical, scientific, and technological aspects of the environment. There is also a concern for environmental quality and aesthetics.

Within the context of the Environmental Studies Content Theme, two important areas that can be investigated using Landsat images are land, food, and fiber resources, and water resources.

Land, Food and Fiber Resources—Included within the scope of this area are such topics as agricultural land use studies; range management; soil mapping and classification; study and evaluation of vegetative cover; soil conservation studies; forest inventory; detection and surveillance of forest fires; detection of insect disease and crop damage; studies of agricultural productivity; and land use study and assessment.

Water Resources—Within the scope of water resource studies, the following topics are dealt with: study of watersheds; drainage basin size and shape; distribution and type of water pollutants; snow/melt and circulation patterns; monitoring lake and reservoir levels; water yield estimates; ocean current studies; streamflow estimates; flood prediction and control; measurement and delineation of

flooded areas; mapping and observation of coastal wetland areas; and monitoring of glaciers, snow, and ice. A study of these topics will bring a better understanding of environmental changes.

## SUGGESTED IMAGES FOR USE IN ENVIRONMENTAL STUDIES

Washington-Baltimore	(1)
Delmarva Peninsula	(4)
Harrisburg, Pennsylvania	(14)
Knoxville, Tennessee	(17)
Southern Florida	(25)*
Mobile, Alabama	(27)*
Cape Canaveral, Florida	(26)
Western Lake Erie	(32)
Chicago, Illinois	(38)*
St. Louis, Missouri	(39)
Mississippi River Flood Sequence	(41, 42)
Yazoo Basin, Mississippi	(45)
Texas-Louisiana Timberland	(46)
Mississippi Delta	(47)
Upper Mississippi River	(52)
Oklahoma Oil Country	(60)
Uranium Country, Utah-Colorado	(77)
Central Wyoming	(97)
Yellowstone National Park	(98)
Big Horn Mts., Wyoming	(99)
W. Wyoming-S.E. Idaho	(100)
Southern Idaho	(101)
U.S.-Canadian Border	(104)*
Mono Lake, California	(124)
Bay Area, California	(126)
Los Angeles, California	(129)
Mississippi River Sequence	(142)
U.S.-Soviet Border	(150)

\*Referred to in activities in this chapter.



Winnipeg, Manitoba	(163)
Amazon River, Brazil	(205)
Bahia Blanca, Argentina	(215)
Zaragoza, Spain	(231)
World's Largest Lake	(260)
Ob River, Siberia	(266)
Arabian Oil Fields	(280)*
The Ganges Delta	(300)
Brahmaputra River	(301)
Yellow River	(315)
African Land Practice	(336)
Sudan	(364)
Nile Delta	(367)

### ACTIVITY 8: IDENTIFYING AND MAPPING CATEGORIES OF LAND USE WITH LANDSAT IMAGERY

1. Select an image from among those listed in the Environmental Studies Content Theme, page 19.
2. Develop a key or legend explaining the use of different colors to represent the different types of land use listed below:
  - a. Farm land ..... Green
  - b. Urban areas ..... Pink
  - c. Recreational areas (such as National Parks) ..... Red
  - d. Airports and airfields ..... Black
  - e. Woodlands ..... Yellow
  - f. Water ..... Blue
  - g. Transportation facilities ... Orange
3. Have the students create a simple land use map by placing a sheet of clear acetate over the image, outlining the boundaries, and coloring in the land use types with the colors given in the legend.
4. Instruct the students to make use of maps or other reference materials to check their land use maps. Note that the descriptive caption provided with each image in *Mission to Earth*... contains information which should be very useful in completing this activity.
5. Using the Landsat Area Calculator in Chapter 6, p. 45, have the students find the area of each type of land use that they have identified on their maps. (Note: some features may be very difficult to measure, for example, airfields).

### ACTIVITY 9: USING LANDSAT IMAGERY TO STUDY MAN'S IMPACT ON THE ENVIRONMENT

1. Have the students select an image from among those recommended for the Environmental Studies Content Theme, page 19.
2. Instruct students to identify and list as many man-made or man-induced features as are visible on the image. Indicate those features which reflect the impact of man's technological innovation and development, such as dams, waterways, irrigation facilities, and others. Examples of many of these can be found on the following plates in *Mission to Earth*:
  - a. Plate 25 Southern Florida
  - b. Plate 27 Mobile, Alabama
  - c. Plate 38 Chicago, Illinois
  - d. Plate 104 U.S.-Canadian Border
  - e. Plate 280 Arabian Oil Fields
3. Using maps and/or other reference materials, discuss how man's technological innovations and his activities have affected the environment. Several examples which might be examined are:
  - a. Plate 38 Chicago, Illinois
  - b. Plate 104 The U.S.-Canadian Border
  - c. Plate 336 African Land Practice
  - d. Plate 367 The Nile Delta

### ACTIVITY 10: OBSERVING TEMPORAL CHANGES IN THE ENVIRONMENT WITH LANDSAT IMAGES

Landsat imagery offers the advantage of showing changes occurring over a nine-day period. This has important implications for the study of temporal changes.

1. Compare any Landsat image(s) with already existing maps of the same area. You may want to select an image of your local area for study. Observe and make note of the changes which have occurred from the time the map was produced and

the date the image was made.

2. Students should be encouraged to look for features, such as reservoirs, highways,

lakes or new airports which have appeared or disappeared since the map was produced.





## CHAPTER

# 4

## CONTENT THEME: **GEOGRAPHY**

# GEOGRAPHY

Geography is the study of the relationship between man and his natural environment. It encompasses all of the forces and processes of nature which impinge upon man.

Included within the scope of geography are land use study and analysis; inventory of the earth's land and water; assessment and measurement of levels of economic activity; physiography of remote areas; population estimates; study of transportation networks; map preparation and revision; and studies of cultural changes wrought by man.

## SUGGESTED IMAGES FOR STUDYING GEOGRAPHY

Delmarva Peninsula	(4)*
New York City and Philadelphia	(5)*
Rocky Coast of Maine	(13)
State of Florida	(23)*
St. Louis, Missouri	(30)*
Mississippi Delta	(47)
Great Salt Lake	(93)
U.S.-Canadian Border	(104)
Oregon and Washington	(105)
N.W. Washington State	(107)
Eastern Washington	(109)
Cascade Range, Oregon	(111)
Reno, Nevada	(117, 118)*
State of California	(121)
Lake Tahoe	(123)
Bay Area, California	(126)
Los Angeles, California	(129)
Island of Hawaii	(135)*

\*Referred to in activities in this chapter.

Brooks Range	(144)
U.S.-Soviet Border	(150)*
Sierra Madre Orientale	(184)
Mexico City	(187)
Salars of Bolivia	(201)
Rio de Janeiro	(211)
Patagonia, Argentina	(218)
The Netherlands	(228)
Rhone Valley, France	(233)
Lake Geneva	(235)
Nürnberg	(238)
Meeting of three Countries: (Iran, Afghanistan and the U.S.S.R.)	(258)
Northern Urals	(265)
Atlas Mountains	(324)
Algeria	(328)
Mt. Kilimanjaro	(359)
Nairobi, Kenya	(361, 362)
Southern Luzon Island, The Philippines	(369)
Central New Guinea	(374)
United States Mosaic	(Inside front and back covers)

## ACTIVITY 11: LOCATING EXAMPLES OF SPECIFIC TYPES OF FEATURES USING LANDSAT IMAGES

Landsat imagery can be used to locate many common types of geographical features. Using the list below and the images suggested for the Geography Content Theme have the students find images in *Mission to Earth*. . . which show examples of each type of feature. List the title of the image on which each feature is located in the appropriate space below:



**Feature****Image (Scene) Title**

1. Alluvial fan \_\_\_\_\_
2. Delta \_\_\_\_\_
3. Meanders \_\_\_\_\_
4. Oxbow lake \_\_\_\_\_
5. River confluence \_\_\_\_\_
6. Estuary \_\_\_\_\_
7. Peninsula \_\_\_\_\_
8. Harbor \_\_\_\_\_
9. Canal \_\_\_\_\_
10. Floodplain \_\_\_\_\_
11. Bay \_\_\_\_\_
12. Reservoir \_\_\_\_\_
13. Lava flow \_\_\_\_\_
14. Fault \_\_\_\_\_
15. Desert \_\_\_\_\_
16. Coastal plain \_\_\_\_\_
17. Bird's foot delta \_\_\_\_\_

**ACTIVITY 12: USING LANDSAT IMAGES AS A BASIS FOR MAPPING**

A map is a representation of the whole earth or a part of the earth on a flat surface. There are five major elements which a map must possess; namely, a TITLE, LEGEND (KEY), SCALE, LATITUDE and LONGITUDE, and DIREC-

TION or ORIENTATION. Landsat images are orthographic because they show the earth as it actually is. These images provide an excellent basis for mapping.

1. Have the students select an image and place a sheet of clear acetate over it.
2. Instruct the students to do the following on the overlay:
  - a. Write a descriptive title for the image selected.

- b. Make a legend (key) for the image. Be sure that each color or symbol used is explained. Prepare the legend as though it were going to be used as a reference by someone who is unfamiliar with Landsat images and false color.
  - c. With the aid of a map and the "Index of Plates" in *Mission to Earth*. . . Appendix C, pp. 453-459, extrapolate the lines of latitude and longitude and place them on the overlay.
  - d. Show the image scale (1 cm = 10 km, or 1 in. represents 16 miles) in fractional, verbal, and graphic form on the overlay.
  - e. Using an atlas or other reference, indicate the direction or orientation of the image. (In most cases, this information is already given on the image and may be traced onto the overlay).
3. Have the students exchange and discuss their "maps" (overlays). This is a useful way of checking the "readability" of the image-maps.

### ACTIVITY 13: CLASSIFYING LANDSAT IMAGES BY GEOGRAPHIC REGION

The United States can be divided into sixteen major geographic regions. This information may be found in most standard geography or physical geography texts. (See Bibliography, pp. 52). A good exercise for teaching students about these regions and for reinforcing this information is given below:

1. Have students use any standard geographic reference book to find and list the sixteen geographic regions of the United States. Observe the boundaries of each region.
2. Have students find and study the major physical characteristics of each region.
3. Using *Mission to Earth*. . . have students classify selected Landsat images of The United States according to geographic region.
4. Students may be asked to select one region and do an intensive study of the area using Landsat images and captions as a source of information.

### ACTIVITY 14: USING SCALE TO COMPUTE DISTANCES ON LANDSAT IMAGES

Landsat images are small scale because of the distance of the satellites from the earth. The result is that one of these relatively small images covers a very large area. The scale of Landsat images is 1:1,000,000 or 1 cm is equivalent to 10 km (1 inch represents 16 miles) on the ground. Because distortions are minimal on Landsat images, they are considered to be orthographic. Landsat images are valuable for such activities as mapping, charting, and computing distances. Individual images can be used very well in measuring distances between various points on the earth surface.

Using the images suggested for each problem below, have students do the following exercises:

- a. *Plate 5 New York City—Philadelphia*  
What is the air distance in kilometers and miles between
  - New York and Philadelphia?
  - Wilmington and Trenton?
  - Reading and Allentown?
- b. *Plate 150 U.S.-Soviet Border*  
What is the distance in kilometers and miles between the coasts of the United States and the U.S.S.R.?
- c. *Plate 4 Delmarva Peninsula*  
In kilometers and miles, what is the approximate length of the C and D Canal?
- d. *Plate 117 Reno, Nevada*  
What is the airline distance between Honey Lake and Pyramid Lake in kilometers and miles?
- e. *Plate 135 Island of Hawaii*
  1. What is the north-south extent of the island of Hawaii in kilometers? miles?
  2. What is the distance between the easternmost and westernmost points of the island of Hawaii in kilometers and miles?
- f. *Plate 23 State of Florida*  
How far north of Lake Okeechobee is Cape Canaveral by airplane in kilometers and miles?
- g. *Plate 30 St. Louis, Missouri*  
How far east of St. Louis is the Carlyle Reservoir in kilometers and miles?



## ACTIVITY 15: LOCATING GEOGRAPHIC FEATURES ON LANDSAT IMAGES

The images found in *Mission to Earth* . . . contain a wealth of information about the earth, particularly those showing outstanding geographical features.

1. Provide the students with a list of selected geographical features and have them locate in *Mission to Earth* . . . an image on which each feature is shown.
2. The list may include features throughout the world, or it may be localized by state, region, or even by continent.

3. A suggested list of such features might include the following:
  - a. Grand Canyon
  - b. Nile Delta
  - c. San Andreas Fault
  - d. Suez Canal
  - e. Crater Lake
  - f. Finger Lakes
  - g. Continental Divide
  - h. Gobi Desert
  - i. A geyser field
  - j. Fall line
  - k. Mojave Desert
  - l. African Rift
  - m. Rocky Mountains
  - n. A fold belt
  - o. Tibetan Plateau

CHAPTER

5

CONTENT THEME:  
**SOCIAL AND  
URBAN STUDIES**





# SOCIAL AND URBAN STUDIES

The social studies are primarily concerned with the nature, development, and manifestations of human relationships. Social studies may be defined as the study of man's interaction with his natural and social environments. Included with the social studies curriculum are units of instruction which are based primarily on concepts taken from the social sciences. Some of the social sciences upon which the social studies draw are economics, history, government, geography, anthropology, and sociology. Also included within the scope of the social studies are the study of mankind's cultural heritage and its characteristics.

Urban studies deal primarily with the study of the growth and expansion of urban places and their characteristics. The current concern in the urban studies is that of understanding the urban revolution of recent decades. Within the scope of urban studies is the study of cities as entities, social and cultural patterns within urban areas, land use patterns and strategies for land use in cities, patterns of urban circulation and movement, the economic base of urbanized areas, the changing nature of the city, theories of urban growth and the political structure of the city.

As the term implies, urban studies include a broad spectrum of concepts, methodologies, terminologies, and strategies drawn from the social sciences.

Boston and Cape Cod	(12)
Charleston, South Carolina	(21)
Cape Canaveral	(26)
Detroit, Michigan	(37)
Chicago, Illinois	(38)
St. Louis, Missouri	(39)
Mississippi Delta	(41, 42)
Lake Country, Minnesota	(53)
Houston, Texas	(63)
Black Hills, S. Dakota	(73)
Colorado Rocky Mts.	(75, 76)
Bay Area, California	(126)
Los Angeles, California	(129)
Montreal	(159)
Ottawa	(161)
Mexico City	(187)
Acapulco	(188)
Rio de Janeiro	(211)
London	(227)
Paris	(229)
Nürnberg	(238)
Vienna	(240)
Rome	(244)
Athens	(248)
The Ukraine	(253)
Southern Viet Nam	(307)
Hong Kong and Canton,	(314)
South China Coast	
Peking, China	(316)
Osaka, Japan	(320)
Tokyo, Japan	(321)
Central New Guinea	(374)

## SUGGESTED IMAGES FOR USE IN SOCIAL AND URBAN STUDIES

Washington-Baltimore	(1)
New York City, Philadelphia	(5)
New York City-Long Island	(6)
Southern New England	(11)

## ACTIVITY 16: STUDYING URBAN SIZE AND FUNCTION WITH LANDSAT IMAGES

1. Have each student select an image from among those suggested for use in the Social and Urban Studies Content Theme.

2. Provide the following information for each student:

### SYMBOLS REPRESENTING URBAN SIZE



Population over 1,000,000



Population between 500,000 and 1,000,000



Population between 200,000 and 500,000



Population between 100,000 and 200,000



Population less than 100,000

3. Have each student do the following:
- Prepare two overlays for the image selected. Sheets of clear acetate and marking pens should be used.  
Overlay 1 — Outline the boundaries of each city or urban area shown on the image selected. Keep in mind that urban areas normally appear blue-gray in color and somewhat circular in form.  
Overlay 2 — Find population statistics for each urban area identified. (An atlas or other references provide such information). Using this data, place the appropriate symbol for urban size over the location of each area.
  - Superimpose your overlays over the image. Using this data, list all the cities shown on the image and the population of each.
  - Using other reference materials, with the image and overlays, answer the following questions:
    - What is the largest city shown on the image?
    - What are the major economic activities carried on in the largest city?
    - What economic activities are carried on in the smaller cities?
    - Discuss the accessibility of the smaller cities to the larger, particularly in terms of transportation networks or linkages which are visi-

ble on the image. According to recent statistics, are these cities decreasing, increasing, or remaining stable in terms of population? What factors are responsible for the changes or stability?

4. Students might enjoy the following activity:
- Using the same image as before, prepare an overlay for urban population. For each city or town on the image give the population that you think each will have attained by the year 2000. Base your projections on current rates of growth and other data which can be found in various reference sources.
  - Discuss these predictions and the reason for making them in class.

### ACTIVITY 17: STUDYING URBAN FORM AND STRUCTURE USING LANDSAT IMAGES

- Select an image of a large city, such as Detroit, Denver, Los Angeles, Tokyo, San Francisco, or others. (See list of images suggested for use in the Social and Urban Studies Content Theme, p. 31).
- Place a sheet of clear acetate over the image, and using a marking pen, define and outline the boundaries of the city. Atlas, highway, or other maps may be used in ascertaining urban boundaries. Some service stations provide free maps of major cities and state road maps which include insets of major urban centers.
- Compare the size of the urban area shown on the image with that shown on the map, paying close attention to differences of scale. On the Landsat images 1 cm represents 10 km (1 inch represents 16 miles).
- On the overlay trace the outline of broad street patterns, where visible.
- Using the background information on "Urban Form and Street Patterns" on page 33, do the following:
  - Identify the type of urban form possessed by the city.
  - Identify the type of street pattern in the city.
  - Using reference maps, identify and label on the overlay as many streets, highways, and main arterials as possible.
- Compare the form of the city shown on the Landsat image with that shown on the



reference map. Discuss the following:

- a. What, if any, changes in form are evident on the Landsat image?
  - b. Look for changes in street patterns or the existence of new or recently completed highways, streets, arterials, etc.
  - c. Has growth or sprawl occurred? If so, in what direction and how much? (The Landsat Area Calculator on page 45 should be used in measuring the amount of growth or sprawl.)
7. For additional study of urban form and street patterns, have students select any number of images showing large cities, and identify the type of urban form and street pattern (where discernible) for each.

## URBAN FORM AND STREET PATTERNS

Urban areas vary in terms of their form and structure. Basically, there are four major types of shape or form which characterize urban areas: (1) compact; (2) elongated or attenuated; (3) fragmented; and (4) prorupt.

A *compact* area is one in which the entire surface of the city is contiguous and equidistant from a common central point. An example of a city with a compact form is Buffalo, New York. An urban area is said to be *elongated* or *attenuated* when its surface is drawn out or extended in one direction. Seattle, Washington is a good example of this type of form. When an area is broken up into separate portions, some of which are separate from the main, it is said to be *fragmented*. The city of San Francisco exhibits such a pattern. San Francisco proper is a rather compact city, but the metropolitan area is fragmented, with such areas as Oakland and Berkeley and a number of other areas comprising portions of the urbanized area of San Francisco. An urban area which exhibits one or more projections or bulges outward from its center is considered *prorupt*. The city of Los Angeles exhibits a prorupt form.

There are two basic types of street patterns found in urban areas, namely: (1) radial; and (2) grid.

The *radial* street pattern is one in which the main streets or highways lead or radiate outward from the center of the city, like spokes in a wheel. The *grid* street pattern consists of streets which cross or intersect each other, usually at right angles.

## ACTIVITY 18: STUDYING SIGNIFICANT SOCIAL ISSUES USING LANDSAT IMAGERY

The Social Studies teacher may devote some time during the school year to the study and discussion of such significant human problems as:

- Problems of food production
- Population pressure and its ramifications
- Industrialization and economic development
- Energy production
- Land use management practices and policies

The technique which might be used to study the above problems is that of *gaming*. The game approach is very useful because, through its use, students can be made aware of the operation of real world processes by playing games which utilize hypothetical situations and conditions.

The game technique involves devising hypothetical cases or situations in which students are provided background materials and given defined rules which must be observed during the course of the game. Students are asked to play roles, such as land use planners, civil servants, government policy making officials, members of the regional development agency in the area studied, citizen's lobby group members, representatives of business and industry, or other groups. The groups are asked to study the situation and suggest solutions to the problems presented in the hypothetical situation using the background materials and other available information.

Some of the situations which the teacher might suggest for study are:

- Pros and cons of creating a new town or city
- Conversion of vacant urban land to industrial uses
- Location of a regional shopping center
- Building a dam and creating an artificial lake or reservoir
- Selection of sites for dumping of sewage and industrial waste

The major advantage of the game approach is that it stimulates much discussion and thought on the part of the students. Students are not only asked to present solutions or strategies, but are required to defend them should alternative solutions be suggested by the other groups.



In such an exercise as that described above, Landsat images of the area(s) under study may be used to great advantage. The images may be used as a primary data source, and the students should be encouraged to extract as much information as they can from the image(s). Landsat images and captions should be supplemented by the other maps, reference materials, as well as classroom resource persons.

### ACTIVITY 19: USING LANDSAT IMAGES IN THE STUDY OF HISTORICAL AND POLITICAL EVENTS

1. Have the students select any historical or political event for study, for example:
  - a. The Westward Movement
  - b. First Battle of the Marne
  - c. Attack on Pearl Harbor
  - d. Battle of Hastings
  - e. The Battle of Gettysburg
  - f. Lewis and Clark Expedition
  - g. Korean War
  - h. The Railroad Building Era
  - i. 1967 Arab-Israeli War
  - j. 1940 Russo-Finnish War
  - k. Civil War-Shenandoah Campaigns
  - l. Space Exploration-Cape Canaveral
  - m. California Gold Rush
2. Have the students gather any available background information concerning the event selected. Make sure the students understand and include the "Where," "When," "Why," and "How" of each event.
3. Have each student find a Landsat image of the area in which the event occurred. Also, find maps and other references which show or illustrate the event.
4. Each student should prepare an overlay for use with the Landsat scene. On the overlay, show the location of strategic sites, or major movements or linkages. In illustrating battles, such as a Civil War or Revolutionary War battle, use arrows, symbols, directional lines, and colors to show major advances, retreats, and other movements.
5. For each event selected, instruct the students to write a brief explanation of what is shown on the overlay, and be able to share their work with the rest of the class.

### ACTIVITY 20: STUDYING ECONOMIC ACTIVITIES USING LANDSAT IMAGES

1. Have each student select a Landsat image for study. Images which can be very useful in this activity are listed on page 31.
2. After allowing time for studying their images, have students locate maps of the area shown on the image. Such maps as land use, economic activity, climate, vegetation and others will be most valuable. The *National Atlas of the United States* can be very helpful. See Bibliography, pp. 51.
3. The students should be provided with the list of economic activities and symbols illustrated below. The list should be discussed and examples of each type of activity given.
4. Instruct students to make an overlay for the image which they have selected. On the overlay indicate by means of the symbols shown below as many economic activities as can be identified on the image.
5. The completed overlays may be used in group or class discussion.

#### Economic Activities



1. Fishing



2. Mining



3. Industry/manufacturing



4. Forestry



5. Agriculture

### ACTIVITY 21: USING THE LANDSAT MOSAIC OF THE UNITED STATES IN THE STUDY OF HISTORY

The Landsat mosaic of the United States should be used in each of the activities suggested below. For each activity, a sheet of clear acetate should be superimposed over the United States Mosaic. Have each student select



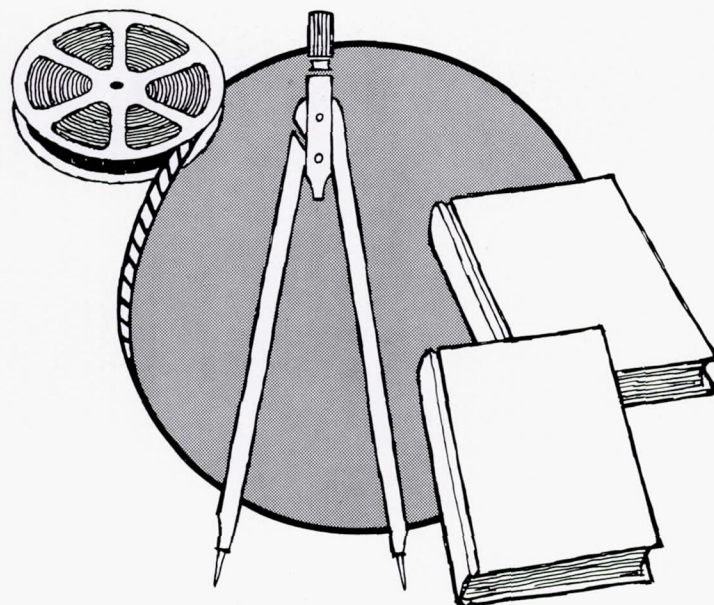
one (or more), of the following activities for completion. Each activity may be completed as a group effort or individually.

1. Show the routes traveled westward by the early settlers. Discuss how the geography of the area influenced the patterns of movement.
2. Using two different colors, indicate the areas that fought on the side of the North and those that fought on the side of the South during the Civil War. Discuss the differences, similarities, and geographic advantages of each side.
3. Show the major battle sites for the following:
  - (1) War of 1812

- (2) Revolutionary War
- (3) Civil War
- (4) Mexican War

4. Outline the territory which comprised the Louisiana Purchase. Trace the routes of the Lewis and Clark expedition.
5. Indicate the major seaports of the U.S. by 1860. Using the supplementary texts and other materials, indicate the factors contributing to the rise of these ports and some of the economic activities which were carried out at the various ports.
6. Trace the route of one or more of the early railroads in the U.S. Discuss their uses and the factors which contributed to their development.

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CHAPTER

6

# SUPPLEMENTARY ACTIVITIES & MATERIALS



# SUPPLEMENTARY ACTIVITIES & MATERIALS

## OTHER RECOMMENDED ACTIVITIES

The activities provided in this section are primarily cross-disciplinary in orientation so that they can be used with any of the Content Themes included in this Guide.

These activities may be assigned as class, small group, or individual projects. Some of them may also be used as evaluation devices or for pre-testing students' knowledge or understanding of concepts in each Content Theme.

### LANDSAT—TOE

LANDSAT-TOE may be used as an educational game or as an evaluative device, i.e., a quiz. Using this, a teacher can check to see how well students understand what can be seen on a Landsat image, whether or not they can relate what they see on a map, aerial photo, etc. to what is shown on the image, and how well they can identify various types of features from the image.

The teacher may want to use the activity as is, or devise certain modifications which would best suit the teaching situation.

### CLASS PARTICIPATION

1. The game should be preceded by a brief description of imagery, and how it is interpreted.
2. Divide the class into two groups, "X" and "O".
3. The students may use atlases, maps, and pencil and paper to find or work out answers to questions.

4. On the board, draw the same diagram as used in the game of tic-tac-toe.
5. Show each team a Landsat image and ask a question concerning the image.
6. Any member of the team may give an answer, once the teacher calls upon him/her. There will only be one answer per team. If, for example, team "O" gives a correct answer, the person giving the answer may mark "O" wherever he desires on the diagram. If team "O" misses an answer, the question goes to Team "X". The object of the game is for the teams to see who can get three "X"'s or "O"'s in a straight line in any direction. The first team to do this is the winner.

### GROUP PARTICIPATION

1. Divide the class into groups of 5 or 6. One person in each group should be designated "Captain".
2. Have two groups play at a time.
3. The students may use atlases, maps, and pencil and paper to work out answers to questions.
4. Follow steps 4-5 in Class Participation description. Instead of allowing any member of the group to answer each question, have the spokesman or group "Captain" give the answer, and insert the team's mark ("X" or "O") on the diagram.
5. The winning groups may challenge each other.

### SMALL GROUP PARTICIPATION

1. Divide the class into groups of two. Each group will be a team.
2. Proceed as suggested in the Group Participation approach to the game.

## USING LANDSAT IMAGE MOSAICS

*Mission to Earth*. . . contains several Landsat image mosaics and outlines of the mosaics of various areas.

Mosaics are made by combining several individual Landsat scenes to produce coverage of an entire geographical area; for example, a state, a group of states, or a country. Outlines of several of the Landsat image mosaics appear on the following pages. Others may be traced directly from those in *Mission to Earth*. . . .

Landsat image mosaics have great potential for classroom use. Here are some suggested uses:

1. Have each student devise a color key and use it to show various features. (For example, vegetation may be shown as green, cities as red, water as yellow, etc.) Then have the student study the mosaic and transfer such data as major cities, vegetation, water features, etc. to the mosaic outline. For classroom discussion, have each student display their map, and explain what the colors represent.
2. Select any two mosaics, and decide upon a theme for study; for example, large cities, natural water features, man-made water features, or geological features. If a student selects large cities as a theme, have the student locate and identify large cities on each mosaic outline. Secondly, compare and contrast the two areas in terms of the number of large cities, their geographic location and other variables.
3. Use the mosaic outlines as a means of evaluating students' ability to visually interpret Landsat images. Have the entire class study a Landsat mosaic and then ask the students to locate certain features on their outlines.

4. Have the students use the outlines to make a series of overlays for the mosaic. The overlays can illustrate such things as:
  - a. Urban areas
  - b. Rivers, lakes, reservoirs
  - c. Geological divisions of the area
  - d. Population centers or clusters
  - e. Physical regions of the area
  - f. Vegetated areas

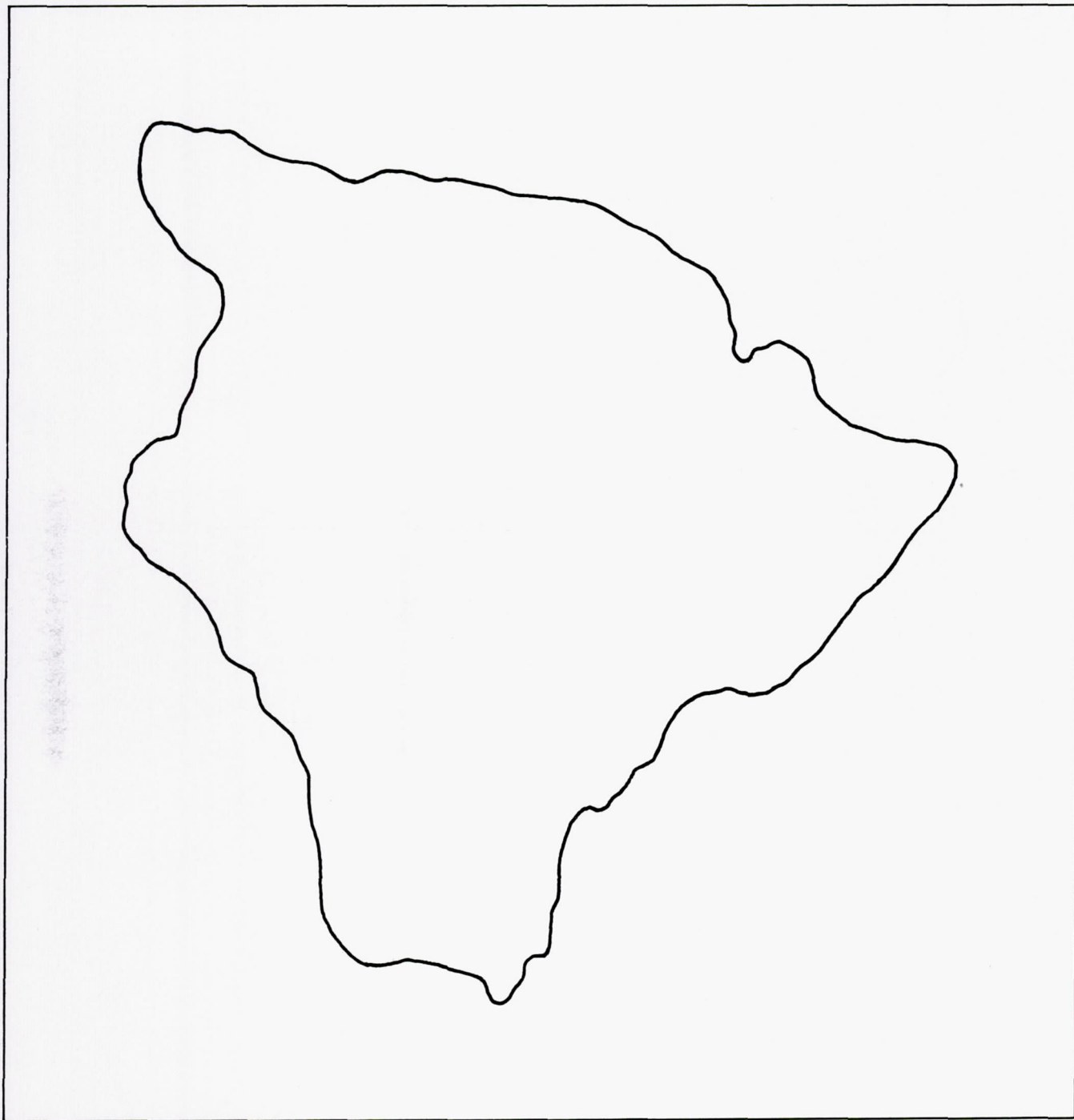
As the teacher becomes more familiar with the imagery and its uses, other ideas will come to mind.

## LANDSAT IMAGE MOSAICS IN MISSION TO EARTH

Each Landsat image mosaic in *Mission to Earth*. . . , with the exception of Plates 140 and 337, is accompanied by an outline of the mosaic and is listed below.

Plate 23	State of Florida
Plate 33	State of Michigan
Plate 43	State of Louisiana
Plate 95	State of Wyoming
Plate 105	States of Oregon and Washington
Plate 113	State of Nevada
Plate 121	State of California
Plate 135	Island of Hawaii
Plate 140	Fairbanks Area, Alaska
Plate 233	Rhone Valley, France
Plate 241	Italy
Plate 271	Southern Red Sea
Plate 273	Northern Red Sea
Plate 387	Southern Iran
Plate 337	Mali
Plate 367	Nile Delta





**PLATE 135**

**ISLAND OF HAWAII**



**PLATE 121**  
**STATE OF CALIFORNIA**





**PLATE 23**  
**STATE OF FLORIDA**

## USING THE UNITED STATES MOSAIC

The mosaic of the conterminous United States can be used for making transparent overlays. See inside front and back cover, *Mission to Earth* . . . . Once these overlays are produced, a wide variety of data may be placed on them. Some examples are as follows:

1. Time zones
2. Physical regions of the U.S.
3. Major rivers, lakes, etc.
4. Major geological features
5. Land use regions
6. Major urban regions
7. Population clusters
8. Soil types
9. Agricultural regions of the U.S.
10. Vegetation areas
11. January/July temperatures
12. Historical areas or sites
13. Voting patterns of the U.S.
14. Climate of the U.S.

Any number of overlays showing various kinds of information can be made and used with the actual Landsat image mosaic of the U.S. The advantage of this method is the ease with which students can see and study relationships between various phenomena.

## INSTRUCTIONAL MATERIALS

### HOW TO USE THE LANDSAT AREA CALCULATOR

The Landsat Area Calculator (LAC) (page 45) is to be used for measuring the areal extent

of features on Landsat images. The LAC is a dot grid which will allow the user to closely approximate the areal dimensions of various features on the earth's surface.

At the scale of the Landsat image (1:1,000,000—1 cm represents 10 km or 1 inch represents 16 miles) each dot and its surrounding space on the LAC represents 40 hectares or 0.4 sq. km.

To determine the approximate area of features on Landsat scenes, do the following:

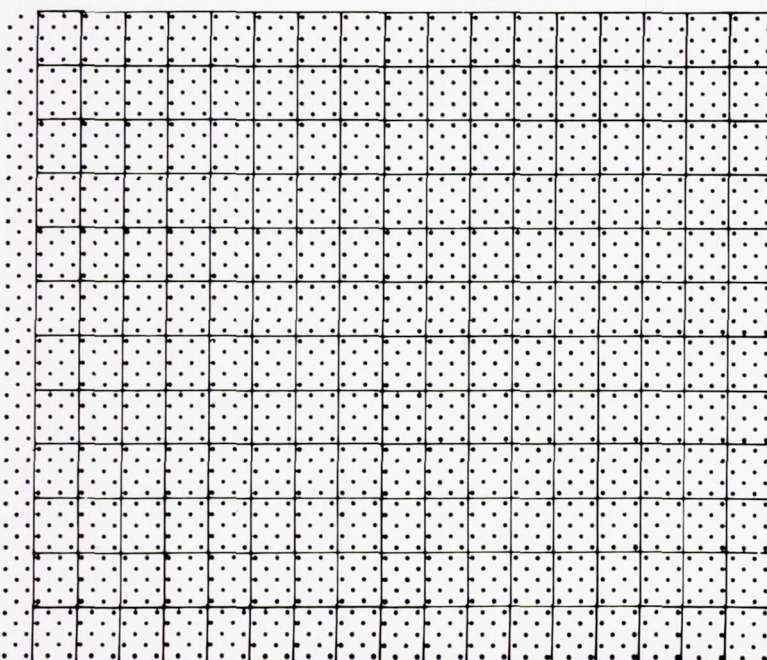
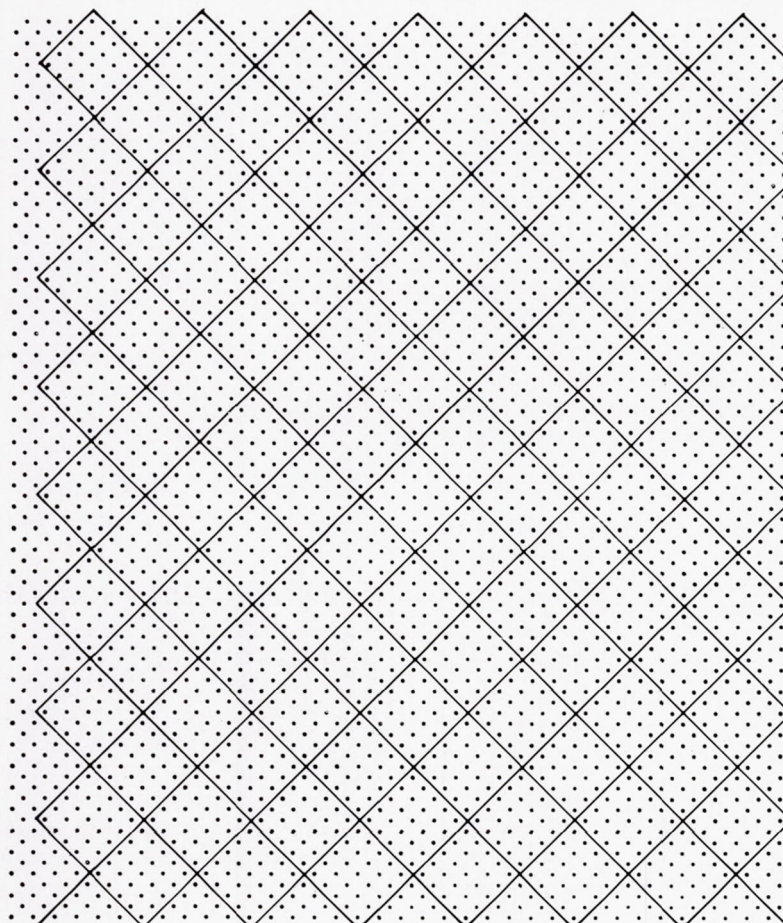
1. Reproduce the LAC diagram on page 45 for use as an overlay. (This may be done by the xerox process or by hand on clear acetate.)
2. Superimpose the LAC overlay on the Landsat scene and outline the boundaries of the feature(s) to be measured.
3. Count the number of dots contained within the boundaries of the feature(s) outlined as well as one-half of the dots whose distance is less than the distance between the dots on the LAC.
4. Multiply the number of dots by 40 to derive the total area in hectares or by 0.4 to derive the total area in sq. km.

Practice in counting dots to measure areas with accuracy can be gained in the following way: Trace several squares from the LAC onto paper, then randomly shift the position of the paper placed beneath the LAC, and count the dots as described in the procedure in step number 3. The actual number of dots in the known area should coincide closely with the number counted after the random placement.



# THE LANDSAT AREA CALCULATOR

Provided by James R. Wray, U.S. Geological Survey, Geography Program.



Scale 1:1,000,000



## LANDSAT ENVIRONMENTAL FILM SERIES FOR SCIENCE AND SOCIAL STUDIES CLASSROOMS

*The National Aeronautics and Space Administration announces the release of an environmental film series under the title of "Landsat: A Satellite for All Seasons."*

*The six fifteen-minute classroom films in this series are designed to help teachers introduce students to understanding the mounting pressures on planet earth in the areas of food production, land use, mineral resources, environmental quality and water resources. The use of satellite information and images in the analysis of these problems is shown vividly in the films along with an assessment of the hope for solutions offered by space technology.*

*Each film can be used individually or in series. Teachers of the social studies as well as teachers of science-related disciplines will find that these films can serve as springboards to class discussion and related activities. A teacher's guide accompanies each film.*

### **The Wet Look**

*HQ 271—Color/sound, 14:30 minutes*

Our "beautiful, wet, blue marble"—an astronaut's description of Earth—yet loads of problems are associated with controlling our water resources so that all of Earth's people may have pure water without droughts and without floods.

Landsat's remote sensing capabilities help water managers resolve problems of supply and control. Hydrologists armed with Landsat imagery have a new tool for estimating areas of mountain snow packs which, when combined with other data, enables them to anticipate volumes of water runoff in the spring melt. Knowing in advance how much water will be moving out of vast mountain areas allows prudent planning for conservation or flood prevention. When floods do occur, Landsat imagery can be used to show the extent of flooding and to monitor changes in flood plain management.

Analysis of Landsat imagery is also contributing to our knowledge of the extent of water pollution and offers promise of early warning of new pollution sources.

### **The Pollution Solution?**

*HQ 276—Color/sound, 14:30 minutes*

America is a nation of plenty, a nation of beauty and a nation with a new awareness of the

necessity for protecting the environment from further degradation.

This film shows how Landsat's remote sensing capabilities can aid in resolving environmental quality problems.

Techniques for locating strip mining areas, determining the amount of land involved and monitoring the rate and extent of reclamation are demonstrated.

Also depicted are examples of ways in which atmospheric and water pollution are located and monitored.

### **The Fractured Look**

*HQ 277—Color/sound, 14:30 minutes*

To understand a part of something, the closer look may be the better look—but to understand the whole of something, the better look may be the look from farther away.

Geologists, being among the first to perceive the implications of studying the earth from orbital altitude, welcomed Landsat's big view of large areas of the earth's crust. They quickly began comparing Landsat imagery with existing geologic maps. Not only were major known fault systems easily observed but many unknown faults were discovered.

Geologic faults are associated with hazards such as earthquakes but they are also keys to locating mineral and water resources. Landsat imagery helps planners locate safe, fault free, new construction sites and helps prospectors obtain clues to hidden mineral wealth.

This film demonstrates how Landsat's remote sensing from outer space is helping us better understand our dynamic and ever-changing planet.

### **Growing Concerns**

*HQ 278—Color/sound, 14:30 minutes*

There is a growing concern that future food production and distribution may not keep pace with the world's population increase.

This film introduces the Landsat satellite as one partial solution to the world's need to survey and monitor agricultural resources. The satellite's imagery is being used experimentally to supplement ground surveys in an effort to increase the accuracy of crop production forecasts within the United States. As an extension of this work, three federal agencies are cooperating in LACIE—the



Large Area Crop Inventory Experiment—to see if Landsat data can be used to improve the accuracy of wheat production estimates on a world-wide basis.

Landsat's comprehensive view of forest and rangelands also provides a new tool to help manage these resources. This imagery can help control insect destruction of crops and trees by pinpointing infested areas for spraying.

## **Land For People, Land For Bears**

*HQ 279—Color/sound 14:30 minutes*

Animals and people use the land: for shelter, for food, for transportation, for recreation, and to make their living.

Today, there is a new awareness of our responsibility to protect and nurture the environment. There is also new technology available to assist. Landsat technology is one example.

This film shows how satellite data can be used for land use mapping and for wildlife habitat mapping on a regular basis. In Florida's Brevard and Orange Counties, Landsat imagery is used to monitor land development. In the western United States, biologists are using Landsat imagery to identify desirable habitats for the relocation of endangered animal species.

## **Remote Possibilities**

*HQ 280—Color/sound, 14:30 minutes*

This final film covers the complete cycle for the collection, processing, and distribution of earth resources information produced by the Landsat system.

In operation, Landsat collects reflected radiation from the earth's natural and cultural features and converts it to digital data. These data are radioed to ground stations and relayed to the NASA Goddard Space Flight Center in Greenbelt, Maryland. Here, the digital tapes are processed so they can be manipulated by most standard computers to produce a wide range of photographic and other products.

The computer compatible tapes are then disseminated by Goddard to cooperating agencies for ultimate use by researchers working around the world on problems described in the other five films.

These films may be borrowed for showing to educational, civic, industrial, professional, youth and similar groups. Local video tape transfer is encouraged. There is no rental charge; however, borrowers must pay the cost of return postage and insurance.

To borrow NASA films, residents of the United States should write to the appropriate NASA Regional Film Library listed below:

NASA Ames Research Center  
Public Affairs Office

Moffett Field, California 94035  
Alaska, Arizona, California, Hawaii, Idaho, Montana, Nevada, Oregon, Utah, Washington, Wyoming

NASA George C. Marshall Space Flight Center  
Public Affairs Office

Marshall Space Flight Center, Alabama 35812  
Alabama, Arkansas, Iowa, Louisiana, Mississippi, Missouri, Tennessee

NASA Goddard Space Flight Center

Public Affairs Office, Educational Programs  
Greenbelt, Maryland 20771  
Delaware, District of Columbia, Maryland, New Jersey, Pennsylvania

NASA John F. Kennedy Space Center  
Public Affairs Office, Code PA-EPS  
Kennedy Space Center, Florida 32899  
Florida, Georgia, Puerto Rico, Virgin Islands

NASA Langley Research Center  
Public Affairs Office, Mail Stop 154  
Langley Station, Hampton, Virginia 23665  
Kentucky, North Carolina, South Carolina, Virginia, West Virginia

NASA Lewis Research Center  
Office of Educational Services  
21000 Brookpark Road, Cleveland, Ohio 44135  
Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin

NASA Lyndon B. Johnson Space Center  
Photographic Technical Lab.  
Audiovisual Office, Code JL-13  
Houston, Texas 77058  
Colorado, Kansas, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas

National Audiovisual Center (GSA)  
Washington, D.C. 20409  
Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, Vermont

Borrowers requiring films on a long-term basis may wish to purchase prints for their own library. NASA films can be purchased from the National Audiovisual Center (GSA), Washington, D.C. 20409



## SOURCES OF LANDSAT IMAGERY

The images referred to in this Guide represent only a fraction of the Landsat imagery that is currently available. Scenes imaged by Landsat 1 and 2 are available for purchase by the general public, and may be obtained in a variety of formats and sizes. Given below is a listing of some of the sources from which Landsat imagery may be obtained.

USER SERVICES UNIT  
EROS DATA CENTER  
Sioux Falls, South Dakota 57198  
Phone: 605-594-6511

Landsat false color composites, black-and-white images, film positives and negatives, and digital data in the form of Computer Compatible Tapes (CCT) are available from this source. Copies of 16 mm microfilm for use in reviewing most types of imagery are also available for purchase from the Data Center. Write or call for information and prices. Request for information about imagery of a specific area will initiate a computerized geographic search, which is made free of charge.

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National Climatic Center  
Satellite Data Services Branch  
World Weather Building  
Room 606, D543  
5200 Auth Road  
Washington, D.C. 20233  
Phone: 301-763-8111

Landsat false color composites, black and white images, transparencies, 35 mm slides, microfilm data on orbits, and 16 mm microfilm data are available for purchase from this source. Write or call for price and information.

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Cartographic Division  
Soil Conservation Service  
Federal Center, Building No. 1  
Hyattsville, MD 20782  
Phone: 301-436-8182

The above source has compiled from Landsat imagery black and white mosaics of the conterminous United States and Alaska. To request further information call or write the above.

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U.S. Geological Survey  
Branch of Distribution  
1200 South Eads Street  
Arlington, VA 22202

The following Landsat products are available from this source:

1. A lithographic copy of the mosaic of the conterminous United States, band 5 or 7, scale 1:5,000,000, price \$1.25.
2. A lithographic copy of the mosaic of Arizona in black and white, and in sepia with cultural and drainage information overprinted, size 48 x 60 inches, scale 1:500,000, price \$1.25 for black and white, \$1.75 for sepia.
3. A lithographic copy of the mosaic of the state of Florida in "false color," size 44 x 58 inches, scale 1:500,000, price \$3.00 per copy.
4. A lithographic copy of the state of New Jersey in "false color," gridded using the Universal Transverse Mercator (UTM) projection, scale 1:500,000, price \$1.25 per copy.
5. A lithographic copy of the Upper Chesapeake Bay in "false color," gridded using the Universal Transverse Mercator Projection, scale 1:500,000, price \$1.50 per copy.

Since the above listing was made, other Landsat materials have become available from this source. As these items are too numerous to mention here, it is suggested that the teacher write to the above address for a current listing of items available and prices.

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National Cartographic Information Center  
U.S. Geological Survey  
507 National Center  
Reston, VA 22092  
Phone: 703-860-6045

The above is primarily an information center which houses browse files for users of Landsat images, and can provide information and U.S. and foreign researches on what Landsat imagery is available. Landsat products in various sizes and formats are available for purchase. These include "false color" composites, black and white prints in Bands 4, 5, 6 and 7, color slides, Computer Compatible Tapes (CCT), negative and positive paper prints, color film positive paper prints.

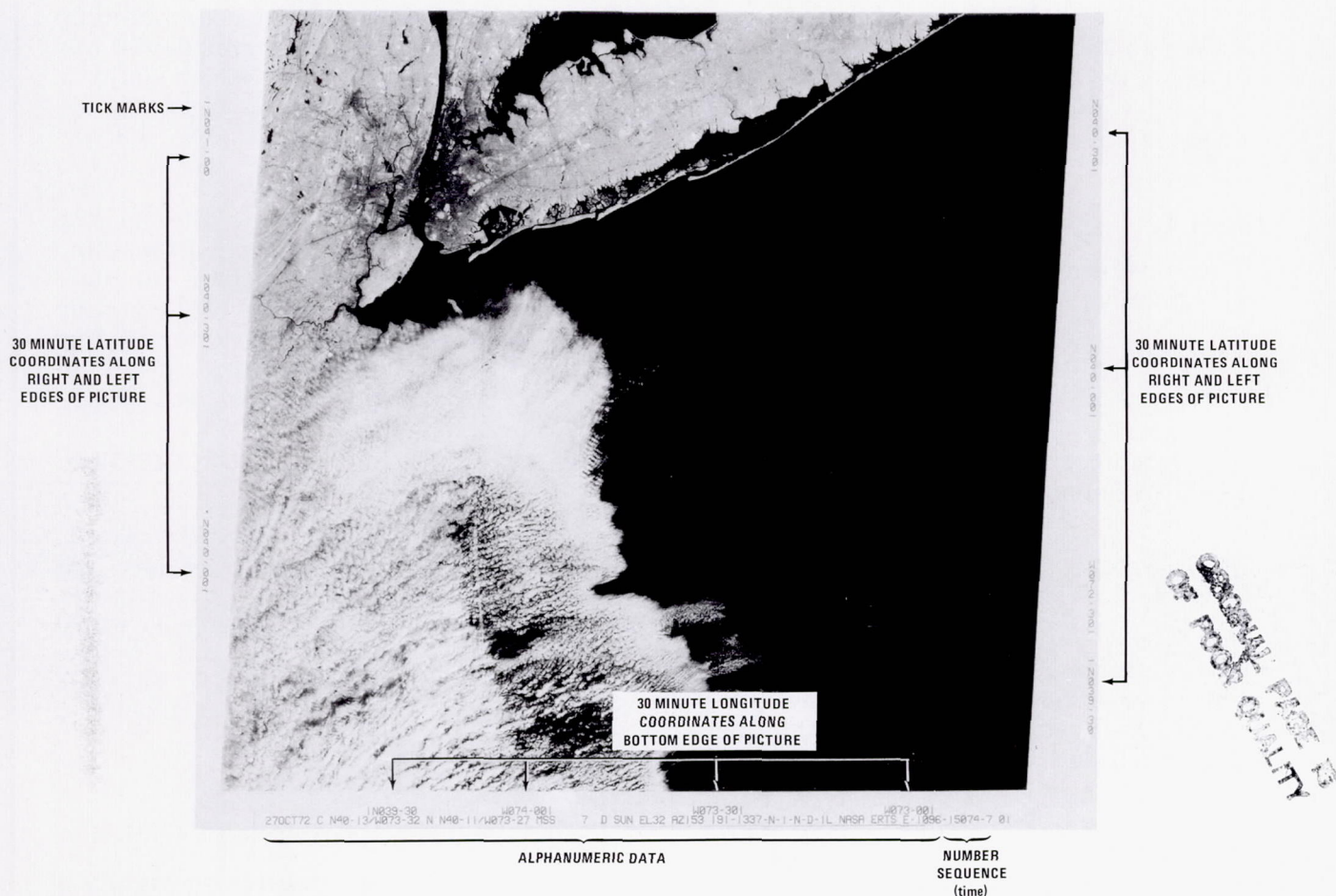
Also available in Bands 4, 5, 6 and 7, and "false color" composite form, are 595 selected scenes, the best quality available imaged by Landsat, which provide complete coverage of the United States. Most of the products available here are in photographic, rather than lithographic form. Write or call for information and prices.



# UNDERSTANDING AND USING LANDSAT ALPHANUMERIC DATA

On each of the Landsat images various data are given to facilitate understanding of each image. This information is located along the bottom margin of each picture and is presented in *alphanumeric form*. The term "alpha-

numeric" means simply the presentation of information by the use of letters (alpha-) and numbers (-numeric). The diagram below illustrates alphanumeric data and its location on the Landsat image.



Understanding of the annotation block data in alphanumeric form is necessary for interpretation and understanding of what each Landsat image shows.

In the following paragraphs, a detailed explanation of the meaning of the Landsat alphanumeric data will be given.

Please refer to the diagram above:

## 27 OCT 72

The date at Greenwich, month and year that the area shown on the image was scanned by the satellite.

## CN40-13/W073-32

Latitude and longitude at the center point of the image, indicated in degrees and minutes.

## N40-11/W073-27

Latitude and longitude of the nadir, or place on earth that is directly beneath the satellite at time the area shown on the image was scanned.

## **MSS 7**

Sensor and NASA Data Processing Facility Code for identification of spectral band in which the image was made. For example, this image was made using MSS Band 7 (0.8 to 1.1  $\mu$ ).

## **"D"**

Refers to "real time" or "direct" transmission, the fact that the image data was instantly relayed back to earth for processing.

## **SUN EL 32**

The sun elevation angle at the midpoint of the image.

## **AZ 153**

The sun azimuth angle from true North at the midpoint of the frame. This is given to the nearest degree.

## **191**

The satellite heading specified to the nearest degree. This indicates the orientation of the image and includes yaw (the rotational or oscillatory movement of the spacecraft about a vertical axis).

## **1337**

The consecutive orbit revolution number.

## **N-1-N-D-1L**

**"N-"** Refers to the data acquisition site. In this instance, the data was recorded at the Network Training and Test Facility (NTTF) at Goddard Space Flight Center, Greenbelt, Maryland.

**"1"** Indicates the image is full size.

**"N"** This indicates that the image was processed using normal processing procedures.

**"D"** This indicates the type of orbit data. In this case the data is "definitive," meaning that the image center was computed by using average orbit deviations to obtain times which could be reproduced.

**"1L"** This indicates a line by line method of signal processing before transmission of data from the satellite to the ground station. "L" refers to the fact that the "low gain option" or normal processing was used.

## **NASA ERTS E**

This identifies the agency, project, and mission. (Note that the name of the satellite has been changed from ERTS to Landsat.)

## **1096-15074-701**

**"1"** — Identifies the ERTS mission.

**"096"** — The day relative to launch at the time the image was made.

**"15"** — Hour at the time the observation was made.

**"07"** — Minutes at the time observation was made.

**"4"** — Tens of seconds at the time observation was made.

**"7"** — The spectral identifier, in this case, MSS Band 7.

**"01"** — Indicates the regeneration number of the processed image.



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# GLOSSARY OF TERMS

This Glossary of terms gives definitions for terms which are not included in the Glossary of *Mission to Earth*. . . Definitions cited here were extracted from the following sources:

W. G. Moore, *Dictionary of Geography*, Penguin, 1968.

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**aggradation**—The building up of the Earth's surface by deposition; specifically the upbuilding performed by a stream in order to establish or maintain uniformity of grade or slope.

**alluvial plain**—A level tract bordering a river on which alluvium is deposited; it may be situated on a floodplain, on a delta, or on an alluvial fan.

**aqueduct**—A large pipe or conduit made for bringing water from a distant source.

**archipelago**—A sea or area in a sea that contains numerous islands; also, the island group itself.

**arid**—Said of a climate characterized by dryness, variously defined as rainfall insufficient for plant life or for crops without irrigation; less than 10 inches of annual rainfall; or a higher evaporation rate than precipitation rate.

**artificial levee**—An artificial embankment, usually of random earth fill, built along the bank of a watercourse or an arm of the sea and designed to protect land from inundation or to confine streamflow to its channel.

**backwater**—Water that is retarded, backed up, or turned back in its course by an obstruction (such as a dam), an opposing current, or the movement of the tide.

**band**—A set of adjacent wavelengths in the electromagnetic spectrum with a common characteristic, such as the visible band or the near infrared (IR) band.

**basalt flow**—Fluid or molten basalt which flows in the form of thin tongues or sheets.

**bay**—A wide indentation into the land formed by the sea or by a lake.

**bayou**—(1) A term variously applied to many local water features in the lower Mississippi River basin and in the Gulf Coast region of the U.S., esp. Louisiana. (2) A sluggish and stagnant stream, characterized by a slow or imperceptible current, that follows a winding course through flat alluvial lowlands, coastal swamps or marshes, or river deltas.

**beveling**—The process of cutting across a geologic structure or landform.

**bifurcation**—The separation or branching of a stream into two parts; a stream branch produced by bifurcation.

**bluff**—Any cliff with a steep broad face.

**bog**—A waterlogged, spongy groundmass, primarily mosses, containing acidic, decaying vegetation which may develop into peat.

**bottom land**—Low-lying, level, usually highly fertile land, especially in the Mississippi Valley region and farther west where the term signifies a grassy lowland formed by deposition of alluvium along the margin of a watercourse.

**brine**—Sea water that, due to evaporation or freezing, contains more than the usual amount of dissolved salts, or about 35%.

**burn scar**—The blackened area left as a result of forest or brush fire. The burned area may be subject to erosion due to the removal of vegetation by burning.

**butte**—A small elevated landform typical of deserts in the southwestern United States.

**canyon**—A long, deep, relatively narrow, steep-sided valley confined between lofty and precipitous walls in a plateau or mountainous area, often with a stream at the bottom; similar to, but larger than, a gorge. It is characteristic of an arid or semiarid area (such as western U.S.) where stream downcutting greatly exceeds weathering; e.g., Grand Canyon.

**cape**—An extensive, somewhat rounded irregularity of land jutting out from the coast into a large body of water, either as a peninsula (e.g., Cape Cod, Mass.) or as a projecting point (e.g., Cape Hatteras, N.C.).

**compression**—An adjustment of the Earth's crust to stress of contraction, as in some rift valleys, or to pressure of overlying sediment, as in geosynclines.

**concentric features**—A system of fractures having a common axis.



**consequent drainage**—Characteristic of a stream, valley, or drainage system whose course or direction is dependent on or controlled by the general form and slope of an existing land surface.

**crystalline**—Rock consisting wholly of crystals or fragments of crystals, especially said of an igneous rock developed through cooling from a molten state and containing no glass, or of a metamorphic rock that has undergone recrystallization as a result of temperature and pressure changes.

**deflation basin**—A topographic basin excavated and maintained by wind erosion which removes unconsolidated material and commonly leaves a rim of resistant rock surrounding the depression.

**deflection**—A relatively spontaneous diversion of a stream, as by warping, alluviation, glaciation, lateral corrosion, volcanic action, or along a shore by the shifting downcurrent of an inlet at the stream mouth.

**deposition**—The laying, placing, or throwing down of any material; specifically the constructive process of accumulation into beds, veins, or irregular masses of any kind of loose, solid, rock material by any natural agent, such as the mechanical settling of sediment from suspension in water, the chemical precipitation of mineral matter by evaporation from solution, or the accumulation of organic material through the processes of death of plants and animals.

**distributary**—An irregular, divergent stream flowing away from the main stream and not returning to it, as in a delta or on an alluvial plain. It may be produced by stream deposition choking the original channel. One of the channels of a braided stream; a channel carrying the water of a stream distributary.

**divide**—The line of separation, or the ridge, summit, or narrow tract of high ground, marking the boundary between two adjacent drainage basins or dividing the surface waters that flow naturally in one direction from those that flow in the opposite direction; the line forming the rim of or enclosing a drainage basin; a line across which no water flows.

**drift ice**—Any ice that has broken apart and drifted from its place of origin by winds and currents, such as a fragment of a floe or a detached iceberg; loose, unattached pieces of floating ice with open water preponderating over ice and navigable with ease. A synonym of pack ice as that term is used in a broad sense.

**drumlin**—A low, smoothly rounded, elongated and oval hill, mound or ridge of compact glacial till, built under the margin of the ice and shaped by its flow, or carved out of an older moraine by readvancing ice; its longer axis is parallel to the direction of movement of the ice. It usually has a blunt nose pointing in the direction from which the ice approached, and a gentler slope tapering in the other direction. Height is 8-60 m, average 30 m; length is 400-2000 m, average 1500 m.

**dry stream**—An intermittent stream when not flowing.

**dune**—A low mound, ridge, bank, or hill of loose, windblown granular material (generally sand, sometimes volcanic ash), either bare or covered with vegetation, capable of movement from place to place but always retaining its own characteristic shape.

**eddy current**—A water current that is generally a circular motion with a different direction from that of the main current. It is a temporary current, usually formed at a point at which a current passes some obstruction, or between two adjacent currents flowing in opposite directions, or at the edge of a permanent current.

**embayment**—The formation of a bay, as by the sea overflowing a depression of the land near the mouth of a river. A bay, either the deep indentation or recess of a shoreline, or the large body of water (as an open bay) thus formed.

**enhancement**—Refers to various processes and techniques designed to render optical densities on imagery more susceptible to interpretation.

**extinct volcano**—A volcano that is not presently erupting and that is not considered likely to do so in the future.

**fault step**—Along a normal fault expressed at the surface, one of a series of thin rock slices along which the fault's total displacement is dispersed.

**floe**—A piece of floating ice other than fast ice or glacier ice, larger than an ice cake and smaller than an ice field.

**flowing glacier**—An actively moving glacier.

**fluvial**—Of or pertaining to a river or rivers. Existing, growing, or living in or about a stream or river. Produced by the action of a stream or river. The term is used by geologists, especially in regard to river flow and river action.

**folding**—The curving or bending of a planar structure such as rock strata, foliation, or cleavage by deformation. The term is generally used for the compression of strata in the formation of fold structures on a broad scale, and sometimes has the connotation of general deformation of which the actual folding is only a part.

**foothill**—A lower, subsidiary hill at the base of a mountain or higher hills.

**fracture**—A general term for any break in a rock, whether or not it causes displacement, due to mechanical failure by stress. Fracture includes cracks, joints and faults.

**Geologic Time Scale**—The Geologic Time Scale subdivides geologic history into units of time based on the formation of certain rocks.

**geosyncline**—A mobile downwarping of the crust of the Earth, either elongate or basin-like, measured in scores of kilometers, which is subsiding as sedimentary and volcanic rocks accumulate to thicknesses of thousands of meters. A geosyncline may form in part of a tectonic cycle in which orogeny follows.

**glaciation**—A collective term for the geologic processes of glacial activity, including erosion and deposition, and the resulting effects of such action on the Earth's surface.

**glade**—A term that usually indicates a clearing between slopes; it can be a high meadow, sometimes marshy and forming the headwaters of a stream, or it can be a low, grassy marsh, which is periodically inundated.



**gorge**—A small narrow, deep valley with nearly vertical rocky walls, enclosed among mountains, smaller than a canyon, and more steep-sided than a ravine; especially a narrow, restricted, steep-walled part of a canyon. A narrow defile or passage between hills or mountains.

**gradient**—The angle between the water surface (of a large stream) or the channel floor (of a small stream) and the horizontal, measured in the direction of flow; the "slope" of the stream.

**gully**—A very small valley, such as a small ravine in a cliff face, or a long, narrow hollow or channel worn in earth or unconsolidated material (as on a hillside) by running water and through which water runs only after a rain or the melting of ice or snow; it is smaller than a gulch.

**headwater**—The source (or sources) and upper part of a stream (especially of a large stream or river), including the upper drainage basin; a stream from this source. The term is usually used in the plural.

**humus**—The generally dark, more or less stable part of the organic matter of the soil so well decomposed that the original sources cannot be identified (sometimes used incorrectly for the total organic matter of the soil, including relatively undecomposed material).

**inlet**—A small, narrow opening, recess, indentation, or other entrance into a coastline or a shore of a lake or river, and through which water penetrates into the land.

**interdune**—Pertaining to the relatively flat surface (sand-free or sand-covered) between dunes; e.g., said of the long, trough-like, wind-swept passage between parallel longitudinal dunes.

**intermittent stream**—(a) A stream or reach of a stream that flows only at certain times of the year, as when it receives water from springs or from some surface source. The term "may be arbitrarily restricted" to a stream that flows "continuously during periods of at least one month." (b) A stream that does not flow continuously, as when water losses from evaporation or seepage exceed the available streamflow.

**intruded, intrusive**—Of or pertaining to intrusion, both the processes and the rock so formed. n. An intrusive rock.—Cf: extrusive. Syn: irruptive.

**isthmus**—A narrow strip or neck of land, bordered on both sides by water, connecting two larger land areas, as a peninsula and the mainland (e.g., Isthmus of Suez) or two continents (e.g., Isthmus of Panama).

**joint**—A surface of actual or potential fracture or parting in a rock, without displacement; the surface is usually plane and often occurs with parallel joints to form part of a joint set.

**kavir**—(a) A term used in Iran for a salt desert; specifically, the Great Kavir of inner Iran, a series of closed basins noted for marshy conditions and high salinities. (b) A playa on a kavir. Syn: kewire; kevir. (c) A term used in Iran for a salt marsh.

**kettle lake**—(a) A body of water occupying a kettle in a pitted outwash plain or in a kettle moraine. (b) cave-in lake.

**lagoon (coast)**—(a) A shallow stretch of seawater, such as a sound, channel, bay, or salt-water lake, near or communicating with the sea and partly or com-

pletely separated from it by a low, narrow, elongate strip of land, such as a reef, barrier island, sandbank, or spit; especially the sheet of water between an offshore coral reef and the mainland. It often extends roughly parallel to the coast, and it may be stagnant. (b) A shallow freshwater pond or lake near or communicating with a larger lake or a river; a stretch of freshwater cut off from a lake by a barrier, as in a depression behind a shore dune; a barrier lake. (c) A shallow body of water enclosed or nearly enclosed within an atoll.

**landfill**—Disposal of waste by burying it under layers of earth materials in low-lying ground.

**landslide**—A general term covering a wide variety of mass movement landforms and processes involving the moderately rapid to rapid (on the order of one foot per year or greater) downslope transport, by means of gravitational body stresses.

**leeward**—(a) The side or slope (as of a hill or prominent rock) sheltered or located away from the wind; downwind. (b) A tidal current running onshore and setting in the same direction as that in which the wind is blowing.—n. The lee side, or the lee direction.

**lime sink**—A saucer-shaped depression in the earth's surface, usually found in a limestone region, through which water may enter the ground and pass along an underground course. It is caused by the solvent action on the rock of rainwater containing carbon dioxide from the atmosphere, and may be enlarged by the collapse of rock above an underground cave. The term pot-hole is sometimes popularly applied to a sink hole. See Karst Region.

**lithology**—(a) The description of rocks, on the basis of such characteristics as color, structures, mineralogic composition, and grain size. (b) The physical character of a rock.

**lock**—A stretch of water in a canal, stream, or dock, enclosed by gates at each end, and used in raising or lowering boats as they pass from one water level to another.

**loess**—A widespread, homogenous, commonly non-stratified, porous, friable, unconsolidated but slightly coherent, usually highly calcareous, fine-grained, blanket deposit (generally less than 30 m thick) of marl or loam, consisting predominately of silt with subordinate grain sizes ranging from clay to fine sand, and covering areas extending from north central Europe to eastern China as well as in the Mississippi Valley and Pacific Northwest of the U.S. It is buff to light yellowish or yellowish brown in color (locally gray, brown, or red). Although source and origin is still a controversial question, loess is now generally believed to be windblown dust of Pleistocene age, carried from desert surfaces, alluvial valleys and outwash plains lying south of the limits of the ice sheets, or from unconsolidated glacial or glaciofluvial deposits uncovered by successive glacial recessions but prior to invasion by a vegetation mat.

**mangrove swamp**—A tropical or subtropical marine swamp characterized by abundant mangrove trees.

**mantle**—A general term for an outer covering of material of one kind or another, such as a regolith; specifically waste mantle.



**meander scar**—A crescentic, concave mark on the face of a bluff or valley wall, produced by the lateral planation of a meandering stream which undercut the bluff, and indicating the abandoned route of the stream.

**meteorite impact crater**—An impact crater formed by the falling of a large meteorite onto a surface.

**panhandle**—A strip of land resembling the handle of a pan, as the northern extension of the state of Texas between Oklahoma and New Mexico.

**payload**—The collection of sensors, supporting instruments, and telemetry systems designed to gather and return data required onboard a spacecraft.

**peninsula**—(a) An elongated body or stretch of land nearly surrounded by water and connected with a larger land area, usually by a neck or an isthmus. (b) A relatively large tract of land jutting out into the water, with or without a well-defined isthmus; e.g., the Italian peninsula.

**plain**—(a) Broadly, any flat area, large or small, at a low elevation; specifically, an extensive region of comparatively flat, smooth, and level to gentle undulating land, having few or no prominent surface irregularities (hills, valleys) but sometimes having a considerable slope, and usually at a low elevation with reference to surrounding areas. A plain may be either forested or bare of trees, and may be formed by deposition or by erosion.

**plateau**—(a) Broadly, any comparatively flat area of great extent and elevation; specifically an extensive land region considerably elevated (more than 150-300 m in altitude) above the adjacent country or above sea level and commonly limited on at least one side by an abrupt descent. A plateau is usually higher and more extensive than a mesa; it may be tectonic, residual, or volcanic in origin.

**population density**—The number of people per unit of area.

**promontory**—(a) A high, prominent projection or point of land, or cliff or rock, jutting out boldly into a body of water beyond the coastline; a headland. (b) A cape, either low-lying or of considerable height, with a bold termination. (c) A bluff or prominent hill overlooking or projecting into a lowland.

**prong**—A subordinate ridge or lesser elevation that projects sharply at right angles to, or in a lateral direction from, the crest or side of a hill, mountain, or other high land surface; a small hill extending from a prominent range of hills or mountains.

**river bottom**—The low-lying alluvial land along a river.

**salient**—Projecting or jutting upward or outward; e.g., a landform that projects or extends outward or upward from its surroundings; e.g., a cape along a shoreline, or a spur from the side of a mountain.

**salt lake**—An inland body of water situated in an arid or semiarid region, having no outlet to the sea, and containing a high concentration of dissolved salts (principally sodium chloride). Examples include the Great Salt Lake in Utah, and the Dead Sea in the Near East.

**sandbar**—A bar or low ridge of sand that borders the shore and is built up, or near, to the water surface by currents in a river or by wave action along the shore of a lake or sea.

**scar**—(a) A cliff, precipice, or other steep, rocky eminence or slope (as on the side of a mountain) where bare rock is well exposed to view; e.g., a limestone face in northern England. Originally, the term referred to a crack or breach; later, an isolated or protruding rock. (b) A rocky shore platform. (c) landslide scar. (d) meander scar.

**sedimentary**—(a) Pertaining to or containing sediment; e.g., a "sedimentary deposit" or a "sedimentary complex." (b) Formed by the deposition of sediment (e.g., a "sedimentary clay"), or pertaining to the process of sedimentation (e.g., "sedimentary volcanism").

**shoal**—(a) A relatively shallow place in a stream, lake, sea, or other body of water; a shallows. (b) A submerged ridge, bank, or bar producing a shoal, consisting of or covered by sand, mud, gravel, or other unconsolidated material, and rising from the bed of a body of water to near the surface so as to constitute a danger to surface navigation; specifically an elevation, or an area of such elevations, at a depth of 10 fathoms (formerly 6) or less, composed of material other than rock or coral. It may be exposed at low water. (c) A rocky area on the sea floor within soundings. (d) A growth of vegetation on the bottom of a deep lake, occurring at any depth.

**slope**—(a) Gradient. (b) The inclined surface of any part of the Earth's surface, as a hillslope; also, a broad part of a continent descending toward an ocean, as the Pacific slope.

**smog**—A fog that is heavily laden with smoke, and is therefore commonest in industrial and densely-populated urban areas. The term was coined from the two words 'smoke' and 'fog'.

**solution**—A process of chemical weathering by which rock material passes into solution; e.g., the dissolution and removal of the calcium carbonate in limestone or chalk by carbonic acid derived from rainwater containing carbon dioxide acquired during its passage through the atmosphere.

**sound**—A relatively long, narrow waterway connecting two larger bodies of water (as a sea or lake with the ocean or another sea) or two parts of the same body, or an arm of the sea forming a channel between a mainland and an island; it is generally wider and more extensive than a strait (coast).

**spit**—(a) A small point or low tongue or narrow embankment of land commonly consisting of sand or gravel deposited by longshore drifting and having one end attached to the mainland and the other terminating in open water, usually the sea; a finger-like extension of the beach. (b) A relatively long, narrow shoal or reef extending from the shore into a body of water.

**strait**—A relatively narrow waterway connecting two larger bodies of water, as the Strait of Gibraltar linking the Atlantic Ocean with the Mediterranean Sea; a small channel.

**stream channel**—The hollow bed where a natural body of surface water flows or may flow; a natural passageway or depression of perceptible extent containing continuously or periodically flowing water, or forming a connecting link between two bodies of water; a watercourse.

**strip mining**—Surficial mining, in which the ore is exposed by removing the overburden. Both coal and metalliferous ores (or iron, copper) are worked in this



way. The term quarrying is reserved for building stone and sand and gravel deposits.

**subsidence**—(a) A local mass movement that involves principally the gradual downward settling or sinking of the solid Earth's surface with little or no horizontal motion and that does not occur along a free surface (not the result of a landslide or failure of a slope). The movement is not restricted in rate, magnitude, or area involved. Subsidence may be due to natural geologic processes such as solution, erosion, oxidation, thawing.

**topography**—The general configuration of a land surface including its relief and the position of its natural and man-made features.

**tropical forest**—A tropical forest where the annual rainfall is at least 100 inches. The region is characterized by tall, lush evergreen trees.

**trough**—(a) Any long and narrow depression in the Earth's surface, such as one between hills or with no surface outlet for drainage; especially a broad, elongated, U-shaped valley, such as a glacial trough or a trench. (b) The channel in which a stream flows.

**truncate**—In crystal structure, to replace the corner of a crystal form with a plane. Such a crystal form is said to be truncated.

**unconformable**—Refers to strata or stratification exhibiting the relation of unconformity to the older underlying rocks; not succeeding the underlying rocks in immediate order of age or not fitting together with them as parts of a continuous whole.

**unconsolidated material**—(a) A sediment that is loosely arranged or unstratified, or whose particles are not cemented together, occurring either at the surface or at depth. (b) Soil material that is in a loosely aggregated form.

**undulation**—(a) A landform having a wavy outline or form; e.g., a desert sand deposit similar to a whaleback but shorter and lacking the definite form of the whaleback. (b) Wripping or scalloped land surface, having a wavy outline or appearance, or resembling waves in form; e.g., a rolling prairie.

**volcanic**—(a) Pertaining to the activities, structures, or rock types of a volcano.

**volcanic crater**—A basinlike, rimmed structure that is usually at the summit of a volcanic cone; its floor is approximately the diameter of the vent. It may be formed by an explosive eruption or by the gradual accumulation of pyroclastic material into a surrounding rim.

**wetlands**—Lands containing much soil moisture.

**wind erosion**—Detachment, transportation, and deposition of loose topsoil by wind action, especially in dust storms in arid or semiarid regions or where a protective mat of vegetation is inadequate or has been removed.

**windward**—The side (as of a shore or reef) located toward the direction from which the wind is blowing; facing the wind, such as the "windward slope" of a dune, up which sand moves by saltation. (b) A tide moving toward the direction from which the wind is blowing.